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Volume I

NEW INSULATION CONSTRUCTIONS FOR AEROSPACE WIRING APPLICATIONS

Volume I: Testing and Evaluation

Ron Soloman
Lynn Woodford
Steve Domalewski

McDonnell Douglas Corporation
McDonnell Aircraft Company
P O Box 516
St Louis, Missouri 63166

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MATERIALS DIRECTORATE
WRIGHT LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6533

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This technical report has been reviewed and is approved for publication.

Ronald H. Williams

RONALD H. WILLIAMS, Actg Chief
Materials Integrity Branch
Systems Support Division
Materials Directorate

FOR THE COMMANDER

Thomas D. Cooper

THOMAS D. COOPER, Chief
Systems Support Division
Materials Directorate

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This test program evaluated existing and new wire insulation constructions in a round wire configuration for aerospace applications. The goal of the program was to identify insulation candidates with balanced electrical, thermal, and mechanical properties. A comprehensive test program was developed to evaluate and statistically rank each wire construction. Testing was conducted using existing military and industry test methods. Forty-three tests were conducted on the wire samples evaluated. Initially ten insulation candidates and two baseline constructions MIL-W-81381 and MIL-W-22759 (cross-linked ETFE) were evaluated using the 15 most important tests. The majority of candidates consisted of composite constructions of polyimide film and a fluoropolymer layer(s). Four of the best performing candidates and the baseline constructions were further evaluated for overall performance by evaluating properties such as abrasion and cut-through resistance, chemical and fluid resistance, dry and wet arc tracking, and flammability and smoke generation. Three composite insulations were identified as having non-arc tracking characteristics,

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good chemical resistance, excellent handling properties, and excellent mechanical properties at room temperature and at temperatures as high as 200°C. Two of the three candidates ranked higher than the two baseline constructions. The third candidate was ranked slightly lower than MIL-W-81381 yet higher than MIL-W-22759 (cross-linked ETFE). Overall the program demonstrated that composite constructions are available which perform as well and in several areas superior to currently available wire insulations. The composite constructions did particularly well in arc tracking tests, mechanical properties at high temperatures, and in flexibility tests.

PREFACE

This final report is work performed under Contract No. F33615-89-C-5605 from February 1989 through January 1991.

The work was performed by McDonnell Aircraft Company (MCAIR), St. Louis, Mo. Mr. Ron Soloman was the program manager and the principle investigator was Ms. Lynn Woodford.

This contract was initiated by Wright Research and Development Center, Materials Laboratory, System Support Division and was completed by the Wright Laboratory, Materials Directorate, System Support Division, Wright Patterson AFB, Dayton, OH 45433-6533. Mr. George Slenski was the project engineer.

Disclaimer: The intent of this report was to identify new wire insulation constructions that can be used for aerospace applications. A particular manufacturer's product is not being endorsed or recommended. New insulations evaluated in this report should be fully characterized by the manufacturer prior to use in aerospace applications.

Acknowledgments: McDonnell Aircraft Company gratefully acknowledges the exceptional support and assistance they received in the conduct of this insulated wire/cable evaluation. All samples of candidate and baseline constructions were supplied without cost by Barcel Wire and Cable Corporation, Brand-Rex Cable Systems Division, Champlain Cable Corporation, E.I. DuPont De Nemours and Company, Filotex, W.L. Gore and Associates, Independent Cable Incorporated, Tensolite Company and Teledyne-Thermatics.

CS 95 conductor was provided without cost by Hudson International Conductors. DuPont provided the relative thermal life test data and the statistical analysis without charge. All round robin testing by Brand Rex, Champlain, Federal Aviation Agency, Filotex, Hudson International, Tensolite and Thermatics was conducted without cost to the program. Westinghouse provided a 270 volt dc generator on a loan basis. Eaton Corporation, Hartman Electrical Manufacturing, ILC Data Device Corporation, Kilovac Corporation, Texas Instruments and Teledyne Solid State provided DC power controllers on a loan basis Industry participation and support was outstanding and provided the test program with much of the material, hardware and technical data required to make a good assessment of the candidate insulations. We are indebted to the people of these companies who so generously gave their time, talents and material in support of this test effort.

EXECUTIVE SUMMARY

This test program had four main objectives: (a) identify and rank aircraft wire insulation performance requirements; (b) develop a test plan to evaluate the performance; (c) identify, test, and rank new wire insulation constructions using the developed test plan; and (d) prepare preliminary specifications for the most promising wire insulation(s). A goal was to identify insulation candidate(s) with balanced properties that are similar in weight and volume to currently available aerospace wiring and manufacturable by more than one company.

Aircraft insulation performance requirements were determined and a test plan was developed to quantify the wire performance. SAE AS 4373, Test Methods for Insulated Electric Wire, was used extensively as the test guide. Performance Requirements were then weighted through the determination and assignment of weight factors to each performance test.

Ten new wire insulation constructions were chosen as test candidates, along with two baseline constructions, which acted as controls for comparison purposes. The performance tests were separated into two categories, Screening and Full Performance. Fifteen stringent tests were selected as the Screening Tests and performed first to identify the candidates with the most desirable properties at the beginning of the program. The four most desirable candidates were selected based upon a statistical analysis of the Screening Test results. These four candidates (provided by Filotex, NEMA,

Tensolite, and Thermatics) and the two baselines were then tested in an additional 28 Full Performance Tests. The two best candidates were selected from a second statistical analysis, encompassing all 43 tests. These top two candidates (provided by Filotex and Tensolite) then underwent Chemical and Thermal Analysis, Assembly, Handling, and Repair tests along with the M22759 baseline.

Cable tests were not included in the overall statistical analysis, however, individual cable statistical analysis showed that the best performing jacket was an extruded PFA provided by Tensolite.

Tests examining arc propagation in 270 Vdc power systems were also conducted. Results showed that none of the 10 original candidates, two baselines, or three additional inorganic constructions tested were able to inhibit arc propagation in a 270 Vdc power system with no additional circuit protection added. However, the addition of selected power controllers to the circuit provided the required protection.

A Round Robin Test program was conducted to verify repeatability and variability among candidate rankings. Seven companies were involved in performing fifteen different tests. Data from all testers, including MCAIR, was compiled and compared. Results reflect some corroboration in ranking, even though there were variations in actual data. Further work may be required to refine the SAE test procedures to achieve more repeatable results.

Preliminary specification sheets were prepared for the four top performing candidates, as these were identified as the most promising. The statistical analysis demonstrated that wire constructions consisting of primarily fluoropolymer layer(s) and a polyimide film layer perform in the range and in certain areas superior to MIL-W-81381/7, /9 and /11 and M22759/44, /33 and /43 wiring. These types of constructions have more balanced properties when compared to MIL-W-81381 and MIL-W-22759 wiring. The top three candidates (Filotex, Tensolite, and Thermatics) when compared to MIL-W-81381 had increased flexibility, did not exhibit arc tracking in wet and dry arc track tests, had an increased temperature capability, but had slightly lower values in the mechanical properties area. When compared to MIL-W-22759 (XL ETFE), the top three candidate constructions had superior mechanical properties in temperatures in excess of 70°C and were superior in flammability and smoke generation tests, yet had less flexibility. The final selection process was based on the statistical analysis of the performance tests, weight and volumes comparable to MIL-W-81381, and the ability to obtain the candidate construction from more than one source. Using the above criteria, an insulation similar to the Thermatics construction is recommended as an alternative to currently available aerospace primary round wiring. Constructions based on the Thermatics candidate should be flight tested in order to correlate laboratory findings with aircraft wiring

installation, maintenance practices, and an exposure to an aircraft operational environment. This construction should be considered as a candidate when evaluating wiring for new aerospace systems.

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1.0 INTRODUCTION

A comprehensive series of assembly and handling, combat damage, electrical, environmental, marking, mechanical, thermal, physical dimension and visual examination tests were conducted to make a comparative evaluation of ten new wire insulation candidates along with two baseline constructions, M81381/7, /9 and /11 and M22759/44, /33 and /43. Tests were conducted primarily according to the proposed draft of SAE AS4373 dated November of 1989, Test Methods for Insulated Electric Wire. The test procedures had been developed to compare wire insulation performance. Minimum performance requirements for aircraft wiring were recommended and are included subsequently in this introduction.

The majority of tests were conducted by the MCAIR Electrical Systems Laboratory from 8 June 1989 to 21 December 1990. The insulation manufacturers performed the Dielectric Constant and Surface Resistance Tests on their own products and submitted the data to MCAIR. E.I. Dupont Company in Wilmington, Delaware performed the Thermal Index Test. Douglas Aircraft Company (DAC) in Long Beach, California performed the Smoke Quantity, Time/Current to Smoke, Wire to Wire Rub, and Wire Surface Markability Tests. McDonnell Douglas Research Laboratories (MDRL) in St. Louis, Missouri performed Chemical and Thermal Analysis on the top two performing candidates and the two baselines. The MCAIR Materials and Process Development Department supervised our Assembly, Handling, Installation, Removal, and Repairability Evaluation on the top two performing

candidates and the M22759 baseline.

MINIMUM PERFORMANCE REQUIREMENTS

This contains the following information for each of the tests in the Initial Screening Tests and the Full Performance Tests that will be performed on new aerospace wire and cable candidates.

- Minimum performance requirements
- Rationale for the minimum performance requirements
- Ranking (weighting) factor for each test
- Rationale for the assignment of the ranking factor

In addition, a straightforward process for determining the weighting values assigned to each test is presented. This process is outlined below.

MCAIR examined each performance requirement in three categories to arrive at a weight.

- Probability of Occurrence Low (1), Moderate (2), High (3)
- Frequency of Occurrence Low (1), Moderate (2), High (3)
- Seriousness of Failure Low (1), Moderate (3), High (5)

The numerical values of low, moderate, or high are added and divided by 2 to arrive at the weight factor for that test. Two is used as a divisor because "Probability" and "Frequency" combined are roughly equal to the importance of "Seriousness." Special situations may override the use of the formula. Rationale is supplied in such cases.

Weight factors provided by Grumman and Lockheed are also included.

As a final step, the MCAIR, Grumman, and Lockheed weights are averaged into a single number (to one decimal place) for each test.

The baseline wire construction for which numerical performance requirements are specified is normally 22 AWG, thin wall, 200°C-rated wire. Also tested are 22 AWG medium wall, 26 AWG thin wall, 22 AWG thin wall 2SJ cable and 26 AWG thin wall 2SJ cable. Not all constructions are tested in all tests. Performance requirements for the 2SJ cable constructions are not specified. Historical performance data for these constructions is more limited, and our test program focuses more heavily on primary wire.

Some tests appear in the "Verification of Retained Properties" series as well as stand-alone tests. Performance requirements for these tests are given twice, once for virgin and once for heat-aged wire.

Tests in McDonnell Aircraft's wire test program were chosen to cover wire use and abuse during installation, operation, battle damage, maintenance and repair. Tests were initially proposed in our PRDA proposal and were grouped into categories such as environmental, mechanical, electrical, thermal, weight and space. Emphasis has been placed on a test program that

will demonstrate a balance of properties. Performance requirements for these tests were determined by consultation and review with a number of sources, including existing wire specifications (MIL-W-22759 and MIL-W-81381), wire and cable manufacturers, McDonnell Aircraft experts, other airframe manufacturers, industry standards committees, the U.S. Air Force, and the U.S. Navy.

Pre-Screen: Impulse Dielectric, Jacket Flaw. All primary wire shall pass 8 KV impulse dielectric test. All jacketed cable shall pass 1.5 KV jacket flaw test. These tests are done on the full length of all wire and cable to check that the wire we start with is properly manufactured and is not damaged. 8 KV impulse was chosen because it is the highest value in military specs and is high enough to detect processing and insulation material flaws without damaging the insulation. Other options that could have been used are 10 KV impulse (some say this is too high, will damage the insulation) and 3.5 KV sinusoidal (net effect similar to 8 KV impulse, and may be more consistent from one test machine to another). 1.5 KV jacket flaw test has been industry standard for over 20 years. No weight factor is given for the dielectric and jacket flaw tests since they are pre-screen on 100% of candidate wire and cable and not part of the itemized list of screening and full performance tests.

1. Dielectric Constant. Dielectric constant shall not be greater than 4.0. 4.0 is close to the maximum dielectric constant in today's insulations; we wanted to include most candidate materials for this test program. Future higher data rate signal wire may benefit from lower dielectric constants, however. Dielectric constant varies with frequency; critical applications may wish to spec dielectric constant at a given frequency. MCAIR Weighting: Because this is a physical property, there are no "occurrences." In most cases, impact of differences in dielectric constant is low. We have assigned this test a 2. Grumman Weight = 2. Lockheed Weight = 2. Average = 2.

2. Corona Inception and Extinction. Requirements are given below for AC and DC inception and extinction.

	Inception	Extinction
DC	340 V_{dc}	300 V_{dc}
AC	250 V_{rms}	230 V_{rms}

DC values assume 270 VDC power with surges up to 340 VDC and steady-state values up to 300 VDC. AC values are taken from standard 205 Vrms line-line aircraft power, with appropriate margin. Corona is especially important in space vehicles. MCAIR Weighting: Probability: Low, Frequency: Low, Seriousness: Moderate/High (eventually degrades wire); or (1+1+4)/2 = 3. Grumman Weight = 4. Lockheed Weight = 3. Average = 3.3.

3. Surface Resistance. Surface resistance shall be > 5 Megohms for one inch. The lowest common value from various present wire specs was chosen. Variations in values in the 5 Megohm and up range do not directly relate to wire performance in aircraft. MCAIR Weighting: Because this is a physical property, their are no "occurrences." In most cases, impact of differences in surface resistance is low. We have assigned this test a 2. Grumman Weight = 2.5. Lockheed Weight = 2. Average = 2.2.

4. Time/Current to Smoke. For 22 AWG, 200°C-rated thin wall wire, no smoke must be generated at currents equal to 150% of free air load, applied for 15 seconds. Rationale is to provide a smokeless wire until circuit breaker trip cuts off current flow. MCAIR Weighting: Probability: Low, Frequency: Low, Seriousness: High; or (1+1+5)/2 = 3.5. Grumman Weight = 3.5. Lockheed Weight = 3. Average = 3.3.

5. Wet Arc Tracking - Harness. No passive or active failures (opens or shorts) are allowed within 24 hours. Shorts are failures because they are a direct safety concern and cause loss of function. Opens are a failure because they cause loss of function. The 24 hour requirement came from the original British test procedure. MCAIR Weighting: Probability: Low, Frequency: Low, Seriousness: High; or (1+1+5)/2 = 3.5. Grumman Weight = 3. Lockheed Weight = 3. Average = 3.2.

6. Wire Fusing Time. For 22 AWG, 200°C-rated thin wall wire at 2.5 times free air current, wire shall conduct for a minimum of 10 seconds before fusing. This test is adapted from original British test procedure. The performance requirement of 10 seconds is intended to give reasonable time for most circuit breakers to function without wire fusing first. MCAIR Weighting: Probability: Low, Frequency: Low, Seriousness: High, or (1+1+5)/2 = 3.5. Grumman Weight = 3. Lockheed Weight = 3. Average = 3.2.

7. Fluid Immersion. After immersion, outer diameter shall increase a maximum of 5%; no cracking shall occur in bend test; no dielectric breakdown is allowed. Performance requirements allow for some absorption (5% O.D. increase), provided physical (bend test) and electrical (dielectric test) failures do not result. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: Moderate, or (3+3+3)/2 = 4.5. Grumman Weight = 5. Lockheed Weight = 4. Average = 4.5.

8. Forced Hydrolysis. For "thermally conditioned" wire, no dielectric breakdown shall occur after 672 hours of exposure. The exposure time of 672 hours (4 weeks) has been arbitrarily chosen to evaluate propensity to absorb water. It is unlikely that installed wire will be continuously exposed to water for this long. Post-exposure testing is limited to dielectric strength test. MCAIR Weighting: Probability: Moderate, Frequency: Moderate, Seriousness: Moderate; or (2+2+3)/2 =

3.5. Grumman Weight = 3. Lockheed Weight = 4. Average = 3.5.

9. Humidity Resistance. Post-exposure insulation resistance shall be at least 5 Megohms for 1,000 feet. The 5 Megohm value came from existing Mil Specs and experience base. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: Moderate; or (3+3+3)/2 = 4.5 Grumman Weight = 5. Lockheed Weight = 4. Average = 4.5.

10. Weight Loss (Outgassing). When preconditioned per the May 1987 SAE test procedure, allowed weight loss at 90-100% relative humidity is 2.0% or less; or 0-5% R.H. it is 1.5% or less. This test is intended to show chemical stability of insulation, but does not identify those compounds outgassed. 2.0% and 1.5% are reasonable values based on MCAIR's B0482 test data. MCAIR Weighting: Probability: Moderate, Frequency: Moderate, Seriousness: Low; or (2+2+1)/2 = 2.5. Grumman Weight = 2. Lockheed Weight = 2. Average = 2.2.

11. Weathering Resistance.

- No cracked or split insulation allowed.
- Color changes shall not preclude identification or original color.
- Must pass bend, voltage withstand tests.

This test measures retention of flexibility and dielectric strength, and the ability to identify the product, after

normal environmental exposure. Such qualities are essential for a wire repeatedly exposed to the open atmosphere. The bend test represents wire used in wheel wells, which is exposed to the open atmosphere and undergoes repeated flexing. MCAIR Weighting: Probability: High but in limited areas (use 2), Frequency: Same, Seriousness: Moderate; or (2+2+3)/2 = 3.5. Grumman Weight = 4. Lockheed Weight = 3. Average = 3.5.

12. Wicking. Wicking between layers of insulation is limited to 0.25 inches as identified by dye travel. Excessive wicking shows insulation manufacturing weaknesses. This moisture can bubble off at higher temperatures and/or degrade insulation characteristics. Moisture between the conductor and insulation is not prohibited and probably will occur. MCAIR Weighting: Probability: Low, Frequency: Low, Seriousness: Moderate; or (1+1+3)/2 = 2.5. Grumman Weight = 4. Lockheed Weight = 4. Average = 3.5.

13. Abrasion. 22 AWG, thin wall, 200°C wire shall withstand the number of abrading cycles for the temperatures and weights given in the table below. Abrasion cycles continue until the abraiding tool makes electrical contact with the wire conductor.

	Ambient			150°C		
	1#	2#	3#	1#	2#	3#
min. cycles	50	10	2	10	1	0

Abrasion is run at two temperatures to assess performance at different thermal environments. Two weights are chosen to represent different severities in abrasion. MDC B0482 was used as a reference in setting minimum cycle requirements. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: High (especially since the effect is cumulative); or (3+3+5)/2 = 5.5, the highest value possible. Grumman Weight = 5. Lockheed Weight = 5. Average = 5.2.

14. Cold Bend.

- No cracking of insulation allowed.
- Must pass voltage withstand.

These requirements have been in military specifications for years. MCAIR Weighting: Probability: Low, Frequency: Low, Seriousness: High; or (1+1+5)/2 = 3.5. Grumman Weight = 3.5. Lockheed Weight = 3. Average = 3.3.

15. Dynamic Cut Through. Performance levels are specified at four temperatures. Requirements are for 22 AWG, thin wall, 200°C wire.

Ambient	70°C	150°C	200°C
10 lbs.	8 lbs.	5 lbs.	3 lbs.

Ambient represents the maintenance environment where cut through damage is most likely to occur, 70°C and 150°C represent realistic high temperature data points and 200°C is the rated temperature. Weight requirements were taken from MDC B0482 data. Weight and tool shape are arbitrary for this

test, but relative performance data is still useful. MCAIR Weighting: Probability: Moderate, Frequency: Moderate, Seriousness: High; or (2+2+5)/2 = 4.5. Grumman Weight = 5. Lockheed Weight = 5. Average = 4.8.

16. Flex Life. Weights used are 20% of conductor break strength. Failure is defined as conductor strand breakage or insulation breakage.

22 AWG, thin wall, 200°C wire shall pass a minimum of 160 flex cycles.

Although wire loading weights are defined as a percentage of conductor break strength, the 26 AWG alloy and the 22 AWG copper wire used in our test program have the same break strength rating, so loading weights will be the same. Performance is very sensitive to the weight value chosen, making the performance requirement (# of flex cycles) somewhat arbitrary. However, the test is very useful for comparison of candidates. Also, failure is defined as failure of the conductor or the insulation, in recognition of the fact that either condition is unacceptable. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: High; or (3+3+5)/2 = 5.5, the highest value possible. Grumman Weight = 3.5. Lockheed Weight = 5. Average = 4.7.

17. Insulation Impact Resistance. No data or experience is available for this test. No performance requirements can be provided. MCAIR Weighting: Probability: Low/Moderate,

Frequency: Low, Seriousness: Moderate/High; or (1.5 + 1 + 4)/2 = 3.3. Grumman Weight = 3. Lockheed Weight = 3. Average = 3.1.

18. <u>Insulation Tensile Strength and Elongation.</u> Performance requirements for 22 AWG, thick and thin wall insulations are as follows:

- Min. insulation tensile strength = 5,000 psi
- Min. elongation = 35%

Performance requirements are commonly used values in present Mil Specs; we see no need to change them. MCAIR Weighting: Like Dielectric Constant (Test #1), this test measures a physical property of the wire, making it difficult to apply our weighting algorithm. We assign this test a weight of 3 because insulation tensile strength and elongation have some impact on wire performance in other tests (unlike dielectric constant, which we rated a 2). Grumman Weight = 3.5. Lockheed Weight = 3. Average = 3.2.

19. <u>Notch Propagation.</u> Performance requirements for the new notch propagation test method (using notch depths of 25% and 50% of wall thickness) are not presently defined because no data or experience is available using the new method. This test will generate valuable performance comparison data, and will help identify quantitative performance requirements. MCAIR Weighting: Probability: High, Frequency: Moderate, Seriousness: High; or (3+2+5)/2 = 5. Grumman Weight = 5.

Lockheed Weight = 5. Average = 5.

20. <u>Stiffness and Springback.</u> Performance requirements are defined for 4 inch specimens of 22 AWG, thin wall, 200°C wire:

Stiffness	Springback
< 1.1 inch-oz.	< 65°

Performance requirements are based on data from MDC B0482 and NAC TR 2333, and the desire to minimize the collective stiffness of multi-wire harnesses. Our test procedure has been changed, however, but in this case, some preliminary testing has enabled us to give performance projections for the new procedure. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: Moderate; or (3+3+3)/2 = 4.5. Grumman Weight = 4. Lockheed Weight = 4. Average = 4.2.

21. <u>Wire to Wire Rub.</u> Wire to wire rub performance requirements are defined for 22 AWG, thick wall, 200°C wire. Individual wires are subject to the following requirements after completion of rub test:

- Must pass 2 million cycles without a failure with either M81381 or M22759 airframe reference wire.

MCAIR Weighting: Probability: High, Frequency: High, Seriousness: High (especially since the effect is cumulative); or (3+3+5)/2 = 5.5, the highest value possible. Grumman Weight = 5. Lockheed Weight = 5. Average = 5.2.

22. Dry Arc Resistance - Harness. Performance requirements are as follows:

- There must be no consumption of insulation attributable to arc tracking.
- The common integrity circuits shall pass voltage withstand.

Consumption of insulation due to arc tracking is not allowed. This requirement basically eliminates any candidate that arc tracks, in whole or in part, although the linear extent of any arc tracking will be used to distinguish performance among candidates that do arc track. To prove whether consumption due to arc tracking occurs, clamp-to-insulation end distance can be measured, specimen can be examined for melt vs. carbonization, and specimens will be preserved for future examination. Also, requiring the common integrity circuits to pass voltage withstand ensures propagation does not occur to nearby wires. Weighting: The Air Force Program Manager has requested that this test be assigned the highest weight factor possible, which is 5.5 under the MCAIR formula.

23. Flammability.

- Afterflame 3 seconds maximum
- Flame Travel: 3 inches maximum
- No tissue flaming allowed (No flaming drippings)

Performance requirements are taken from established Mil Specs and there is no reason to change them. MCAIR Weighting: Probability: Moderate, Frequency: Low, Seriousness: High; or

(2+1+5)/2 = 4. Grumman Weight = 5. Lockheed Weight = 4. Average = 4.3.

24. Smoke Quantity. For 22 AWG, thin wall, 200°C wire, preliminary performance requirement is:

D_s - 20 minutes shall be 45 or less

Performance requirements are preliminary and came from MDC B0482 as projected to this test. MCAIR Weighting: Probability: Moderate, Frequency: Low, Seriousness: High; or (2+1+5)/2 = 4. Grumman Weight = 5. Lockheed Weight = 4. Average = 4.3.

25. Thermal Index. The thermal index is computed using the projected 15,000 hour life based on the ASTM D3032, Section 14. The minimum thermal index shall be 200°C for our tests. The 15,000 hour value is accepted as representative of military aircraft. MCAIR Weighting: Probability: High, Frequency: Moderate, Seriousness: Moderate; or (3+2+3)/2 = 4. Grumman Weight = 4. Lockheed Weight = 4. Average = 4.

26. Thermal Shock. Performance requirements are defined as follows for 22 AWG, thin wall, 200°C wire:

The maximum insulation length change (shrinkage or expansion) of a 5 foot sample shall be 0.0625 inches per end. No insulation flaring is allowed.

Wire shrinkage/expansion is typical of present requirements for many aircraft wires in Mil Specs. MCAIR Weighting:

Probability: High, Frequency: Moderate, Seriousness: Moderate; or (3+2+3)/2 = 4. Grumman Weight = 4. Lockheed Weight = 4. Average = 4.

27. <u>Toxicity.</u> Due to difficulty by MCAIR and others in the industry in specifying this test, no specific performance requirements are given. The test will be run to obtain comparative wire performance. Any numerical performance value (toxicity index) assigned at this time would be arbitrary. Weighting: We have been requested by the Air Force Program Manager to assign this test a weight factor of 5.

28. <u>Verification of Retained Properties.</u> The comprehensiveness of this test makes it possibly the most important test in the program. Performance requirements and weighting factors are given separately for each test conducted after the heat aging is complete. Specimens are heat aged for 1,000 hours at 200°C and then subjected to the following tests: (Performance requirements are for 22 AWG, thin wall, 200°C wire.) An average weight of 5.5 was assigned.

MCAIR has provided individual weight factors for this test as noted above. Grumman and Lockheed both weigh the overall series of tests as a 5.

<u>Abrasion.</u> 22 AWG, thin wall, 200°C wire shall withstand the number of abraiding cycles for the temperature and weights given in the table below.

Abrasion cycles continue until the abraiding tool makes electrical contact with the wire conductor.

	Ambient			150°C		
	1#	2#	3#	1#	2#	3#
min. cycles	50	10	2	--	--	--

Abrasion is also run prior to thermal aging (see test #13, "Abrasion"). Performance requirements are based on MDC B0482 test data. Three weights are chosen to represent different severities in abrasion. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: High, or (3+3+5)/2 = 5.5

Dynamic Cut Through. Performance levels are specified at four temperatures. Requirements are for 22 AWG, thin wall, 200°C wire.

Ambient	70°C	150°C	200°C
9 lbs.	7 lbs.	4 lbs.	2 lbs.

Ambient represents the maintenance environment where cut through damage is most likely to occur, 70°C and 150°C represent realistic high temperature data points and 200°C is the rated temperature. Weight requirements were taken from MDC B0482 data. Weight and tool shape are arbitrary for this test, but relative performance data is still useful. Dynamic Cut Through is also run prior to thermal aging (see test #15). Post-thermal aging requirements are

derated slightly from requirements for virgin material. MCAIR Weighting: Probability: Moderate, Frequency: Moderate, Seriousness: High; or (2+2+5)/2 = 4.5.

Flex Life. Weights used are 20% of conductor break strength. Failure is defined as conductor strand breakage or insulation breakage.

> Thermally aged 22 AWG, thin wall, 200°C wire shall pass a minimum of 120 flex cycles.

Although wire loading weights are defined as a percentage of conductor break strength, the 26 AWG alloy and the 22 AWG copper wire used in our test program have the same break strength rating, so loading weights will be the same. Performance is affected by the weight value chosen, making the performance requirements (# of flex cycles) somewhat arbitrary. However, the test is very useful for comparison of candidates. Also, failure is defined as failure of the conductor or the insulation, in recognition of the fact that either condition is unacceptable. See test #16 for the flex life test on virgin wire. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: High; or (3+3+5)/2 = 5.5.

Notch Propagation. Performance requirements for the new notch propagation test method (using notch depths of 30% and 67% of wall thickness) are not presently defined because no data or experience is available using the new method. This test will generate valuable performance comparison data, and will help identify the quantitative performance requirements. This test is also performed on virgin wire (see test #19). Post-thermal aging performance requirements will probably be derated from those for virgin material. MCAIR Weighting: Probability: High, Frequency: Moderate, Seriousness: High; or (3+2+5)/2 = 5.

Voltage Withstand (Wet Dielectric). Performance requirement is 2.5 KV. 2.5 KV is a standard value; we saw no reason to modify it. Use of this requirements post-exposure implies no derating of the standard due to the heat aging. Voltage Withstand is not performed prior to exposure. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: High; or (3+3+5)/2 = 5.5.

Insulation Resistance. Performance requirement is 2,000 Megohms for 1,000 feet. 2,000 Megohms is a common value and we saw no reason to modify it. Again, use of this requirement post-exposure implies

no derating of the standard due to the heat aging. Insulation Resistance is not performed prior to exposure. MCAIR Weighting: Probability: Moderate, Frequency: Moderate, Seriousness: High; or (2+2+5)/2 = 4.5.

Examine Product.

- Insulation: There must be no cracking, dolamination, color changes beyond recognition, or other degradation.
- Conductor: There must be no corrosion or degradation.

MCAIR Weighting: Probability: Low, Frequency: Moderate, Seriousness: Moderate; or (1+2+3)/2 = 3.

29. Finished Diameter. Outer diameter requirements for the wire sizes used in this test program are as follows:

	22 AWG med. wall	22 AWG thin wall	26 AWG thin wall
min. inches	0.045	0.038	0.030
max. inches	0.054	0.045	0.034

Requirements come from the original SAE table which is based on existing Mil Spec wire slash sheets. Minimum 26 AWG thin wall size was increased from 0.028" to 0.030" because connector grommets do not seal below 0.030". MCAIR Weighting: Probability: High, Frequency: High, Seriousness: Moderate, or (3+3+2)/2 = 4.5. Grumman Weight = 4. Lockheed Weight = 4.

Average = 4.2.

30. Finished Weight. Maximum weights, in lb./1000 ft., are given below for the three primary wire constructions used in this test program.

	22 AWG med. wall	22 AWG thin wall	26 AWG thin wall
max. weight	4.3	3.0	1.4

Maximum weight values come from the original SAE table which is based on existing Mil Spec wire slash sheets; it is felt that the new constructions should be compatible. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: Moderate; or (3+3+3)/2 = 4.5. Grumman Weight = 4. Lockheed Weight = 4. Average = 4.2.

31. Wire Surface Markability. After marking and subsequent environmental exposure, the mark on 22 AWG, thin wall, 200°C wire shall remain legible upon examination by the unaided eye.

The marking process must not degrade the insulation. Hence, all specimens are tested for dielectric strength. Marks must also be permanent, hence their ability to withstand fluids, weathering, and thermal aging is determined. It is felt that alphanumeric characters on 26 AWG wire can never be easily readable, so the legibility requirement is only imposed on the 22 AWG size. MCAIR Weighting: Probability: High, Frequency: High, Seriousness: Low; or (3+3+1)/2 = 3.5. Grumman Weight =

4. Lockheed Weight = 4. Average = 3.8.

32. <u>Crush Resistance.</u> No information is available for performance requirements. MCAIR Weighting: Probability: Moderate, Frequency: Low, Seriousness: Moderate, or (2+1+3)/2 = 3. Grumman Weight = 3. Lockheed Weight = 3. Average = 3.

33. <u>Aging Stability - SJ Cable.</u> MCAIR Weighting: Probability: High, Frequency: Moderate, Seriousness: Low; or (3+2+1)/2 = 3. Grumman Weight = 3. Lockheed Weight = 3. Average = 3.

34. <u>Jacket Wall Thickness - SJ Cable.</u> MCAIR Weighting: Probability: High, Frequency: High, Seriousness: Low; or (3+3+1)/2 = 3.5. Grumman Weight = 3.5. Lockheed Weight = 3. Average = 3.3.

35. <u>Workmanship.</u> Workmanship will include inspection of the wire and cable specimens for the following flaws:

- Embedded dirt or foreign material
- Surface flaws on outer layer (cracks, splits, bubbles, irregularities)
- Unraveling or delamination of tape wraps
- Visible flaws in conductor or shield
- Non-uniformity of color

Requirements are typical indications of quality of workmanship

for tape wrapped and extruded wire and cable constructions. The weighting algorithm does not apply to this test. Based primarily on "Seriousness", MCAIR assigns workmanship a weight of 3. Grumman Weight = 3. Lockheed Weight = 3. Average = 3.

2.0 DESCRIPTION OF TEST ARTICLE

The test program evaluated new insulation constructions for wire and cable. The test specimens required were 22 gauge, 8.6 mil wall, airframe wire; 22 and 26 gauge, 5.8 mil wall, hook up wire; and 22 and 26 gauge, two conductor, twisted, shielded and jacketed cable. Silver plated copper (SPC) conductor was requested for the 22 gauge samples and silver plated copper high strength alloy, CS95, conductor was requested for the 26 gauge samples. The Filotex 26 gauge and M22759/33-26 used PD-135 high strength alloy. The shield construction for the cable samples was 0.0015 inch thick flat copper braid with silver plating and 85% minimum shield coverage. Jacket construction was not specified by the test program. The 12 gauge, 8.6 mil wall, airframe wire and 16 gauge, 5.8 mil wall, hook up wire, were requested late in the test program for evaluation in a Dry Arc Propagation Test proposed by the British Standards Institute (BSI).

The test specimens received for the test program are presented in Table 2.1 with MCAIR's spool reference number. Three separate material submissions were made during the test program. Materials from the first submission are characterized by a 100 series spool reference number. Second submission materials are characterized by a 200 series spool reference number. A final submission of 12 and 16 gauge constructions are characterized by *200 and #200 series spool reference numbers, respectively. A description of the insulation candidate constructions is presented in Table 2.2.

TABLE 2.1 - WIRE AND CABLE TEST SPECIMENS

SPOOL REFERENCE	VENDOR	GAUGE	CONSTRUCTION	PART NUMBER
*201	INDEPENDENT	12 AWG	AIRFRAME WIRE	M81381/11-12
101 & 201	INDEPENDENT	22 AWG	AIRFRAME WIRE	M81381/11-22
102 & 202	TENSOLITE	22 AWG	HOOK UP WIRE	M81381/7-22
103 & 203	BARCEL	26 AWG	HOOK UP WIRE	M81381/9-26
104 & 204	TENSOLITE	22 AWG	2 COND. CABLE	ST5M1247F22-2SJ
105 & 205	BARCEL	26 AWG	2 COND. CABLE	ST5M1247F26A2SJ
*206	BRAND REX	12 AWG	AIRFRAME WIRE	M22759/43-12
#206	BRAND REX	16 AWG	HOOK UP WIRE	M22759/44-16
106 & 206	BRAND REX	22 AWG	AIRFRAME WIRE	M22759/43-22
107 & 207	CHAMPLAIN	22 AWG	HOOK UP WIRE	M22759/44-22
108 & 208	BRAND REX	26 AWG	HOOK UP WIRE	M22759/33-26
109 & 209	CHAMPLAIN	22 AWG	2 COND. CABLE	5M2619-22-2SJ
110 & 210	BRAND REX	26 AWG	2 COND. CABLE	5M2619-26A2SJ
111	BARCEL	22 AWG	AIRFRAME WIRE	---------------
112	BARCEL	22 AWG	HOOK UP WIRE	---------------
113	BARCEL	26 AWG	HOOK UP WIRE	---------------
114	BARCEL	22 AWG	2 COND. CABLE	---------------
115	BARCEL	26 AWG	2 COND. CABLE	---------------
116	BRAND REX	22 AWG	AIRFRAME WIRE	---------------
117	BRAND REX	22 AWG	HOOK UP WIRE	---------------
118	BRAND REX	26 AWG	HOOK UP WIRE	---------------
119	BRAND REX	22 AWG	2 COND. CABLE	---------------
120	BRAND REX	26 AWG	2 COND. CABLE	---------------
121	CHAMPLAIN	22 AWG	AIRFRAME WIRE	---------------
122	CHAMPLAIN	22 AWG	HOOK UP WIRE	---------------
123	CHAMPLAIN	26 AWG	HOOK UP WIRE	---------------
124	CHAMPLAIN	22 AWG	2 COND. CABLE	---------------
125	CHAMPLAIN	26 AWG	2 COND. CABLE	---------------
126	DUPONT	22 AWG	AIRFRAME WIRE	---------------
127	DUPONT	22 AWG	HOOK UP WIRE	---------------
128	DUPONT	26 AWG	HOOK UP WIRE	---------------
129	DUPONT	22 AWG	2 COND. CABLE	---------------
130	DUPONT	26 AWG	2 COND. CABLE	---------------
131	GORE	22 AWG	AIRFRAME WIRE	---------------
132	GORE	22 AWG	HOOK UP WIRE	---------------
133	GORE	26 AWG	HOOK UP WIRE	---------------
134	GORE	22 AWG	2 COND. CABLE	---------------
135	GORE	26 AWG	2 COND. CABLE	---------------

TABLE 2.1 - WIRE AND CABLE TEST SPECIMENS (CONT.)

SPOOL REFERENCE	VENDOR	GAUGE	CONSTRUCTION	PART NUMBER
*236	FILOTEX	12 AWG	AIRFRAME WIRE	---------------
#236	FILOTEX	16 AWG	HOOK UP WIRE	---------------
136 & 236	FILOTEX	22 AWG	AIRFRAME WIRE	---------------
137 & 237	FILOTEX	22 AWG	HOOK UP WIRE	---------------
138 & 238	FILOTEX	26 AWG	HOOK UP WIRE	---------------
239	FILOTEX	22 AWG	2 COND. CABLE	---------------
240	FILOTEX	26 AWG	2 COND. CABLE	---------------
*241	TENSOLITE	12 AWG	AIRFRAME WIRE	---------------
#241	TENSOLITE	16 AWG	HOOK UP WIRE	---------------
141 & 241	TENSOLITE	22 AWG	AIRFRAME WIRE	---------------
142 & 242	TENSOLITE	22 AWG	HOOK UP WIRE	---------------
143 & 243	TENSOLITE	26 AWG	HOOK UP WIRE	---------------
144 & 244	TENSOLITE	22 AWG	2 COND. CABLE	---------------
145 & 245	TENSOLITE	26 AWG	2 COND. CABLE	---------------
*246	THERMATICS	12 AWG	AIRFRAME WIRE	---------------
#246	THERMATICS	16 AWG	HOOK UP WIRE	---------------
146 & 246	THERMATICS	22 AWG	AIRFRAME WIRE	---------------
147 & 247	THERMATICS	22 AWG	HOOK UP WIRE	---------------
148 & 248	THERMATICS	26 AWG	HOOK UP WIRE	---------------
149 & 249	THERMATICS	22 AWG	2 COND. CABLE	---------------
150 & 250	THERMATICS	26 AWG	2 COND. CABLE	---------------
151	NEMA #2	22 AWG	AIRFRAME WIRE	---------------
152	NEMA #2	22 AWG	HOOK UP WIRE	---------------
153	NEMA #2	26 AWG	HOOK UP WIRE	---------------
154	NEMA #2	22 AWG	2 COND. CABLE	---------------
155	NEMA #2	26 AWG	2 COND. CABLE	---------------
*256	NEMA #3	12 AWG	AIRFRAME WIRE	---------------
#256	NEMA #3	16 AWG	HOOK UP WIRE	---------------
156 & 256	NEMA #3	22 AWG	AIRFRAME WIRE	---------------
157 & 257	NEMA #3	22 AWG	HOOK UP WIRE	---------------
158 & 258	NEMA #3	26 AWG	HOOK UP WIRE	---------------
159 & 259	NEMA #3	22 AWG	2 COND. CABLE	---------------
160 & 260	NEMA #3	22 AWG	2 COND. CABLE	---------------

NEMA = NATIONAL ELECTRICAL MANUFACTURE'S ASSOCIATION

TABLE 2.2 - DESCRIPTION OF INSULATION CONSTRUCTIONS

VENDOR	CONSTRUCTION	DESCRIPTION
INDEPENDENT	MIL-W-81381/11 (101 AND 201)	029 KAPTON TAPE (50% MIN. OL) / 616 KAPTON TAPE (50% MIN. OL) / POLYIMIDE TOPCOAT
TENSOLITE	MIL-W-81381/7 (102 AND 202)	616 KAPTON TAPE (50% MIN. OL) / 616 KAPTON TAPE (50% MIN. OL) / POLYIMIDE TOPCOAT
BARCEL	MIL-W-81381/9 (103 AND 203)	616 KAPTON TAPE (50% MIN. OL) / 616 KAPTON TAPE (50% MIN. OL) / POLYIMIDE TOPCOAT
BRAND REX	MIL-W-22759/43 (106 AND 206)	DUAL EXTRUSION OF XL ETFE
CHAMPLAIN	MIL-W-22759/44 (107 AND 207)	SINGLE EXTRUSION OF XL ETFE
BRAND REX	MIL-W-22759/33 (108 AND 208)	SINGLE EXTRUSION OF XL ETFE
BARCEL	BARCEL #1 (111 TO 113)	2919 KAPTON (50% OL) / UNSINTERED PTFE TAPE, BUTT WRAP
BRAND REX	BRAND REX #1 (116 TO 118)	XL ETFE TAPE (50% OL) / 616 KAPTON (50% OL) / XL ETFE TAPE (50% OL)
CHAMPLAIN	CHAMPLAIN #1 (121 TO 123)	2919 KAPTON (50% OL) / EXTRUDED XL ETFE
DUPONT	DUPONT #1 (126 TO 128)	NEW POLYIMIDE-FLUOROPOLYMER TAPE, (50% OL) / NEW POLYIMIDE-FLUOROPOLYMER TAPE (50% OL) / FLUOROPOLYMER

ABBREVIATIONS:

029 = 2.0 MIL POLYIMIDE, 0.5 MIL FEP
2919 = 0.5 MIL FLUOROCARBON (PTFE), 1 MIL POLYIMIDE, 0.5 MIL FLUOROCARBON (PTFE)
616 = 0.1 MIL FLUOROCARBON (FEP), 1 MIL POLYIMIDE, 0.1 MIL FLUOROCARBON (FEP)
XL = CROSSLINKED
OL = OVERLAP
ETFE = ETHYLENE TETRAFLUOROETHYLENE
PTFE = POLY TETRAFLUOROETHYLENE

TABLE 2.2 - DESCRIPTION OF INSULATION CONSTRUCTIONS (CONT.)

VENDOR	CONSTRUCTION	DESCRIPTION
FILOTEX	FILOTEX (136 TO 138)	PTFE EXTRUSION / 616 KAPTON (50% MIN. OL) / PTFE DISPERSION *
FILOTEX	FILOTEX (236 TO 238)	PTFE EXTRUSION / 616 KAPTON (50% MIN. OL) / FEP DISPERSION
FILOTEX	FILOTEX (JACKET) (239 TO 240)	3 MIL UNSINTERED PTFE TAPE (49% OL) / 616 KAPTON TAPE (53% OL)
GORE	GORE #3 (131 TO 133)	PTFE (50% OL) / HSCR PTFE (50% OL)
TENSOLITE	TENSOLITE #3 (141 TO 143) (241 TO 243)	200AJ919 (PTFE, H, PTFE) (50% MIN. OL) / PTFE TAPE (50% MIN. OL)
TENSOLITE	TENSOLITE #3 (JACKET) (144 TO 145) (244 TO 245)	EXTRUDED PFA
THERMATICS	THERMATICS #3 (146 TO 148) (246 TO 248)	MODIFIED PTFE TAPE (50% MIN. OL) / TPT TAPE,(MODIFIED PTFE, H, MODIFIED PTFE), (50% MIN. OL) / MODIFIED PTFE TAPE (50% MIN. OL) / PTFE DISPERSION

ABBREVIATIONS:

* - 22 GAUGE CONDUCTOR IS NICKEL PLATED INSTEAD OF SILVER PLATED AND THE 26 GAUGE CONDUCTOR IS SILVER PLATED PD-135.
H = POLYIMIDE FILM
HSCR = HIGH STRENGTH CRUSH RESISTANT
PFA = PERFLUOROALKOXY
200AJ919 = 0.5 MIL FLUOROCARBON (PTFE), 1 MIL POLYIMIDE, 0.5 MIL FLUOROCARBON (PTFE)
H = POLYIMIDE FILM
616 = 0.1 MIL FLUOROCARBON (FEP), 1 MIL POLYIMIDE, 0.1 MIL FLUOROCARBON (FEP)
XL = CROSSLINKED
OL = OVERLAP
ETFE = ETHYLENE TETRAFLUOROETHYLENE
PTFE = POLYTETRAFLUOROETHYLENE

TABLE 2.2 - DESCRIPTION OF INSULATION CONSTRUCTIONS (CONT.)

VENDOR	CONSTRUCTION	DESCRIPTION
THERMATICS	THERMATICS #3 (JACKET) (149 TO 150) (249 TO 250)	616 KAPTON TAPE (50% MIN. OL) / UNSINTERED PTFE TAPE (50% MIN. OL) CROSS WRAPPED TO BASE TAPE
NEMA #2	NEMA #2 (151 TO 153)	PTFE TAPE / 616 (50% OL) / PTFE TAPE
NEMA #3	NEMA #3 (156 TO 158) (256 TO 258)	616 KAPTON (45-50% OL) / EXTRUDED XL ETFE
NEMA #3	NEMA #3 (JACKET) (159 TO 160) (259 TO 260)	019 KAPTON FEP SIDE UP (48% MIN. OL) / DOUBLE BONDABLE, CAST PTFE TAPE, (48% MIN. OL) CROSS WRAPPED TO BASE TAPE

ABBREVIATIONS:

616 = 0.1 MIL FLUOROCARBON (FEP), 1 MIL POLYIMIDE, 0.1 MIL FLUOROCARBON (FEP)
XL = CROSSLINKED
OL = OVERLAP
ETFE = ETHYLENE TETRAFLUOROETHYLENE
PTFE = POLYTETRAFLUOROETHYLENE

3.0 SCREENING TEST PROCEDURES AND RESULTS

MCAIR conducted the screening test sequence on ten candidate and two baseline constructions to select insulation candidates with promise for the highest performance. Twenty tests listed in Table 3.1 were conducted as the screening portion of the test program. These tests were selected because of their high probability of identifying inherent weaknesses of the insulation candidates.

The screening tests enabled the program to conduct more comprehensive and extensive full performance tests only on the four most outstanding candidates. The full performance candidates were chosen by statistical analysis of the data acquired throughout the screening test sequence. The statistical analysis provided an objective evaluation of the insulation candidate's performance.

TABLE 3.1 - SCREENING TEST SUMMARY

SAE AS 4373 METHOD	TEST	22 AWG AIRFRAME WIRE	20 AWG HOOKUP WIRE	26 AWG HOOKUP WIRE	22 AWG CABLE	26 AWG CABLE
(1)	EXAMINE PRODUCT	X	X	X	X	X
(2)	WORKMANSHIP	X	X	X	X	X
(3)	WIRE WALL THICKNESS	X	X	X		
301	DRY ARC RESISTANCE AND FAULT PROPAGATION		X	X		
401	CONDUCTOR DIAMETER	X	X	X		
503	IMPULSE DIELECTRIC	X	X	X		
504	INSULATION RESISTANCE	X	X	X		
(4)	SPARK TEST				X	X
(5)	DRY DIELECTRIC TEST				X	X
510	VOLTAGE WITHSTAND	X	X	X		
601	FLUID IMMERSION		X			
701	ABRASION	X	X			
703	DYNAMIC CUT THROUGH	X	X	X		
(6)	FLEX LIFE	X	X	X		
707	NOTCH PROPAGATION	X	X	X		
708	STIFFNESS & SPRINGBACK	X	X	X		
801	FLAMMABILITY	X	X		X	
(7)	TOXICITY	X	X		X	
901	FINISHED DIAMETER	X	X	X	X	X
902	FINISHED WEIGHT	X	X	X	X	X

(1) - Performed according to SAE AS 4372, Paragraph 3.1.4
(2) - Performed according to SAE AS 4372, Paragraph 3.1.4
(3) - Performed according to ASTM D3032, Section 15.4.1.3
(4) - Performed using Method 503 as a guide
(5) - Performed using Method 503 as a guide
(6) - Performed according to MDC B0482
(7) - Performed according to Naval Engineering Standard 713, Issue 2

3.1 GENERAL

3.1.1 EXAMINE PRODUCT.

3.1.1.1 Scope: The Examine Product Test involved the visual examination of the specimens that were thermal aged for 1000 hours at 200°C (392°F).

3.1.1.2 Reference Procedure: The Examine Product evaluation conformed to SAE AS4372, Performance Requirements for Wire, Electric, Insulated Copper or Copper Alloy, Paragraph 3.1.4.

3.1.1.3 Specimens: A one foot segment of thermal aged 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire was cut from each sample for the Examine Product Test. The specimens were thermal aged for 1000 hours at 200°C (392°F).

3.1.1.4 Test Equipment: A Bausch and Lomb Microscope (MD 121434) set to magnify at 10 power was used to aid in the examination of the specimen if anomalies required further investigation.

3.1.1.5 Test Procedure: Each specimen was examined to search for the following:

(A.) Insulation Cracking
(B.) Color Change beyond Recognition
(C.) Delamination
(D.) Other Degradations

Also, one inch of insulation was removed from both ends of the one foot specimen to examine the difficulties in stripping and to examine the conductor for corrosion or degradation of plating.

3.1.1.6 Test Results: The following denote other degradations that were encountered in the examination:

(1.) Specimen Rather Stiff
(2.) Specimen Difficult to Strip
(3.) Specimen Cracks when Bent
(4.) Air Pockets Observed in Insulation

The NEMA #2 specimens (151, 152, and 153) outer insulation layers adhered to themselves due to the thermal aging process. This layer was identified as an ink jet printable topcoat that the manufacturer applied by mistake. The remaining layers of insulation appeared to be unaffected by the thermal aging process.

The results of the examination of the thermal aged specimens are presented in Tables 3.2 through 3.4.

TABLE 3.2 - EXAMINATION OF THERMAL AGED 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INSUL. CRACK	COLOR CHANGE	DELAMINATION	INSULATION ANOMALIES
101	M81381	PASS	PASS	PASS	(1.)
106	M22759	PASS	FAIL	PASS	PASS
111	BARCEL #1	PASS	PASS	PASS	PASS
116	BRAND REX #1	PASS	FAIL	PASS	(2.)
121	CHAMPLAIN #1	PASS	FAIL	PASS	(1.)
126	DUPONT #1	FAIL	PASS	PASS	(1.)
131	GORE #3	PASS	PASS	PASS	(1.)
136	FILOTEX	PASS	PASS	PASS	PASS
141	TENSOLITE #3	PASS	PASS	PASS	PASS
146	THERMATICS #3	PASS	PASS	PASS	PASS
151	NEMA #2	PASS	FAIL	PASS	(2.)
156	NEMA #3	PASS	FAIL	PASS	(3.)

TABLE 3.3 - EXAMINATION OF THERMAL AGED 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INSUL. CRACK	COLOR CHANGE	DELAMINATION	INSULATION ANOMALIES
102	M81381	PASS	PASS	PASS	(1.)
107	M22759	PASS	FAIL	PASS	PASS
112	BARCEL #1	PASS	PASS	PASS	PASS
117	BRAND REX #1	PASS	FAIL	FAIL	(2.)
122	CHAMPLAIN #1	PASS	FAIL	PASS	(1.)
127	DUPONT #1	FAIL	FAIL	PASS	PASS
132	GORE #3	PASS	PASS	PASS	PASS
137	FILOTEX	PASS	PASS	PASS	PASS
142	TENSOLITE #3	PASS	PASS	PASS	PASS
147	THERMATICS #3	PASS	PASS	PASS	PASS
152	NEMA #2	PASS	FAIL	PASS	PASS
157	NEMA #3	PASS	FAIL	PASS	(3.)

(1.) Specimen was stiff.
(2.) Specimen was difficult to strip.
(3.) Specimen cracked when bent.

TABLE 3.4 - EXAMINATION OF THERMAL AGED
26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INSUL. CRACK	COLOR CHANGE	DELAMINATION	INSULATION ANOMALIES
103	M81381	PASS	PASS	PASS	(2.)
108	M22759	PASS	FAIL	PASS	PASS
113	BARCEL #1	PASS	PASS	PASS	(2.)
118	BRAND REX #1	PASS	FAIL	PASS	PASS
123	CHAMPLAIN #1	PASS	FAIL	PASS	(2.)
128	DUPONT #1	FAIL	PASS	PASS	(4.)
133	GORE #3	PASS	PASS	PASS	PASS
138	FILOTEX	PASS	PASS	PASS	(2.)
143	TENSOLITE #3	PASS	PASS	PASS	PASS
148	THERMATICS #3	PASS	PASS	PASS	PASS
153	NEMA #2	PASS	FAIL	PASS	(2.)
158	NEMA #3	PASS	FAIL	PASS	(2.)

(2.) Specimen was difficult to strip.
(4.) Air pockets were observed in the insulation.

3.1.2 WORKMANSHIP.

3.1.2.1 Scope: The Workmanship Test was used to examine the manufacturer's workmanship qualities of finished wire and cable.

3.1.2.2 Reference Procedure: The Workmanship examination conformed to SAE AS4372, Performance Requirements for Wire, Electric, Insulated Copper or Copper Alloy, Paragraph 3.1.4.

3.1.2.3 Specimens: The workmanship specimen utilized 10 foot finished wire and cable weight specimens for the examination.

3.1.2.4 Test Equipment: A Bausch and Lomb Microscope (MD 121434) set to magnify at 10 power was used to aid in the examination of the specimen if anomalies required further investigation.

3.1.2.5 Test Procedure: All specimens underwent a visual workmanship examination on unconditioned wire or cable. The visual examination inspected for the following areas:

(A.) Any embedded dirt or foreign material present in the insulation
(B.) Any surface flaws observed on the outer insulation (cracks, bubbles, air pockets, etc.)
(C.) Any delamination of the tape wraps
(D.) Any visible defects in the conductor or shield braid.
(E.) Non-uniformity of color

One inch of insulation was removed from both ends of the specimen to examine the difficulties in stripping and to examine the conductor for corrosion or degradations.

The examination was conducted without the aid of magnification but if the particular flaw required further examination, the previously referenced microscope was used. The results of the examination were recorded.

3.1.2.6 **Test Results:** Detailed descriptions of the investigation are presented in Tables 3.5 through 3.9.

TABLE 3.5 - WORKMANSHIP INSPECTION OF 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	FOREIGN MATERIAL	SURFACE FLAWS	DELAM.	COND. DEFECTS	UNIFORM COLOR
101	M81381	PASS	PASS	PASS	PASS	PASS
106	M22759	PASS	(1.)	PASS	PASS	PASS
111	BARCEL #1	PASS	(1.)	PASS	PASS	PASS
116	BRAND REX #1	(2.)	PASS	(4.)	PASS	(1.)
121	CHAMPLAIN #1	PASS	PASS	PASS	PASS	PASS
126	DUPONT #1	PASS	PASS	PASS	PASS	PASS
131	GORE #3	PASS	PASS	PASS	PASS	PASS
136	FILOTEX	PASS	PASS	PASS	PASS	PASS
141	TENSOLITE #3	PASS	(2.)	PASS	PASS	PASS
146	THERMATICS #3	PASS	PASS	PASS	PASS	PASS
151	NEMA #2	PASS	PASS	PASS	PASS	PASS
156	NEMA #3	PASS	(3.)	PASS	PASS	PASS

(1.) Air pockets observed in wire insulation which resulted in a color change at the pocket.
(2.) Black specs, most likely, were observed in the insulation.
(3.) Non-uniform application of insulating material, a lump was detected.
(4.) The tape edges exhibited signs of delamination along the length of the specimen.

TABLE 3.6 - WORKMANSHIP INSPECTION OF 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	FOREIGN MATERIAL	SURFACE FLAWS	DELAM.	COND. DEFECTS	UNIFORM COLOR
102	M81381	PASS	(1.)	PASS	PASS	PASS
107	M22759	PASS	PASS	PASS	PASS	PASS
112	BARCEL #1	PASS	PASS	PASS	PASS	PASS
117	BRAND REX #1	PASS	PASS	(4.)	PASS	PASS
122	CHAMPLAIN #1	PASS	PASS	PASS	PASS	PASS
127	DUPONT #1	PASS	PASS	PASS	PASS	PASS
132	GORE #3	PASS	PASS	(6.)	PASS	PASS
137	FILOTEX	PASS	PASS	PASS	PASS	PASS
142	TENSOLITE #3	PASS	PASS	PASS	PASS	(5.)
147	THERMATICS #3	PASS	(2.)	PASS	PASS	PASS
152	NEMA #2	PASS	PASS	PASS	PASS	PASS
157	NEMA #3	PASS	PASS	PASS	PASS	PASS

TABLE 3.7 - WORKMANSHIP INSPECTION OF 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	FOREIGN MATERIAL	SURFACE FLAWS	DELAM.	COND. DEFECTS	UNIFORM COLOR
103	M81381	PASS	(1.)	PASS	PASS	PASS
108	M22759	PASS	(1.)	PASS	PASS	PASS
113	BARCEL #1	PASS	PASS	PASS	PASS	PASS
118	BRAND REX #1	PASS	PASS	(1.)	PASS	PASS
123	CHAMPLAIN #1	PASS	PASS	PASS	PASS	PASS
128	DUPONT #1	PASS	(7.)	PASS	PASS	PASS
133	GORE #3	PASS	PASS	PASS	PASS	PASS
138	FILOTEX	PASS	PASS	PASS	PASS	PASS
143	TENSOLITE #3	PASS	PASS	PASS	PASS	PASS
148	THERMATICS #3	PASS	PASS	PASS	PASS	PASS
153	NEMA #2	PASS	PASS	PASS	PASS	PASS
158	NEMA #3	PASS	(1.)	PASS	PASS	PASS

(1.) Air pockets observed in wire insulation and resulted in a color change.
(2.) Spots, probably dirt, were observed in the insulation.
(4.) The tape edges exhibited signs of delamination along the length of the specimen.
(5.) Color variations observed throughout the length of the specimen.
(6.) The insulation strings off in fine hair like strands when stripped.
(7.) One crack observed in top layer.

TABLE 3.8 - WORKMANSHIP INSPECTION OF
22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	FOREIGN MATERIAL	SURFACE FLAWS	DELAM.	SHIELD DEFECTS	UNIFORM COLOR
104	M81381	PASS	PASS	PASS	PASS	PASS
109	M22759	PASS	PASS	PASS	(8.)	PASS
114	BARCEL #1	PASS	(1.)	PASS	PASS	PASS
119	BRAND REX #1	PASS	PASS	(9.)	PASS	PASS
124	CHAMPLAIN #1	PASS	PASS	PASS	PASS	PASS
129	DUPONT #1	PASS	(2.)	PASS	PASS	PASS
134	GORE #3	PASS	PASS	PASS	PASS	PASS
139	FILOTEX	PASS	PASS	PASS	PASS	PASS
144	TENSOLITE #3	PASS	(1.)	PASS	PASS	PASS
149	THERMATICS #3	PASS	PASS	PASS	PASS	PASS
154	NEMA #2	PASS	(1.)	PASS	PASS	PASS
159	NEMA #3	PASS	PASS	PASS	PASS	PASS

TABLE 3.9 - WORKMANSHIP INSPECTION OF
26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	FOREIGN MATERIAL	SURFACE FLAWS	DELAM.	SHIELD DEFECTS	UNIFORM COLOR
105	M81381	PASS	PASS	(4.)	PASS	PASS
110	M22759	PASS	PASS	PASS	PASS	PASS
115	BARCEL #1	PASS	(3.)	PASS	PASS	PASS
120	BRAND REX #1	PASS	PASS	(9.)	PASS	PASS
125	CHAMPLAIN #1	PASS	PASS	PASS	PASS	PASS
130	DUPONT #1	PASS	PASS	PASS	PASS	PASS
135	GORE #3	PASS	PASS	PASS	PASS	PASS
140	FILOTEX	PASS	PASS	PASS	PASS	PASS
145	TENSOLITE #3	(2.)	(1.)	PASS	(8.)	PASS
150	THERMATICS #3	PASS	PASS	PASS	PASS	PASS
155	NEMA #2	PASS	(1.)	PASS	PASS	PASS
160	NEMA #3	PASS	PASS	PASS	PASS	PASS

(1.) Air pockets observed in cable jacket which resulted in a color change at the pockets.
(2.) An apparent burn mark was observed on the insulation.
(3.) Non-uniform application of jacket material, a thin, one foot section was wrinkled.
(4.) The tape edges of the jacket exhibited signs of delamination
(8.) Shield has irregular gaps in braiding.
(9.) The primary conductors' insulation unraveled when stripped.

3.2 ASSEMBLY, HANDLING, AND REPAIR TESTS

3.2.1 CALCULATED WALL THICKNESS OF FINISHED WIRE.

3.2.1.1 Scope: The Calculated Wall Thickness of Finished Wire was used to determine an average finished wire wall thickness.

3.2.1.2 Reference Procedure: The calculation used to determine the wall thickness, was referenced in American Society for Testing and Materials D3032, Section 15.4.1.3.

3.2.1.3 Specimens: The average wall thickness was determined for 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire.

3.2.1.4 Test Equipment: No test equipment was required.

3.2.1.5 Test Procedure: The calculated wall thickness of finished wire was determined by using the previously acquired data from the Finished Wire Diameter Test and the Conductor Diameter Test.

The value for the wall thickness was determined by taking the difference between the average wire diameter and the average conductor diameter and dividing that

value by two as shown in the following relationship:

$$\text{Wall Thickness} = (D_{wire} - D_{conductor}) / 2$$

where:

D_{wire} = average diameter of the wire in inches

$D_{conductor}$ = average diameter of the conductor in inches

The calculated wall thickness of finished wire was recorded.

3.2.1.6 Test Results: The calculated average wall thickness test results are presented in Tables 3.10 through 3.12 with a graphical representation of the data in Figure 3.1.

TABLE 3.10 - CALCULATED AVERAGE WALL THICKNESS OF FINISHED WIRE ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	CALCULATED WALL THICKNESS (INCHES)
101	M81381	0.0101
106	M22759	0.0124
111	BARCEL #1	0.0103
116	BRAND REX #1	0.0108
121	CHAMPLAIN #1	0.0126
126	DUPONT #1	0.0085
131	GORE #3	0.0085
136	FILOTEX	0.0087
141	TENSOLITE #3	0.0094
146	THERMATICS #3	0.0082
151	NEMA #2	0.0090
156	NEMA #3	0.0086

TABLE 3.11 - CALCULATED AVERAGE WALL THICKNESS OF FINISHED WIRE ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	CALCULATED WALL THICKNESS (INCHES)
102	M81381	0.0070
107	M22759	0.0060
112	BARCEL #1	0.0067
117	BRAND REX #1	0.0058
122	CHAMPLAIN #1	0.0069
127	DUPONT #1	0.0062
132	GORE #3	0.0053
137	FILOTEX	0.0060
142	TENSOLITE #3	0.0075
147	THERMATICS #3	0.0058
152	NEMA #2	0.0071
157	NEMA #3	0.0067

TABLE 3.12 - CALCULATED AVERAGE WALL THICKNESS OF FINISHED WIRE ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	CALCULATED WALL THICKNESS (INCHES)
103	M81381	0.0056
108	M22759	0.0062
113	BARCEL #1	0.0057
118	BRAND REX #1	0.0067
123	CHAMPLAIN #1	0.0076
128	DUPONT #1	0.0060
133	GORE #3	0.0052
138	FILOTEX	0.0052
143	TENSOLITE #3	0.0075
148	THERMATICS #3	0.0056
153	NEMA #2	0.0075
158	NEMA #3	0.0063

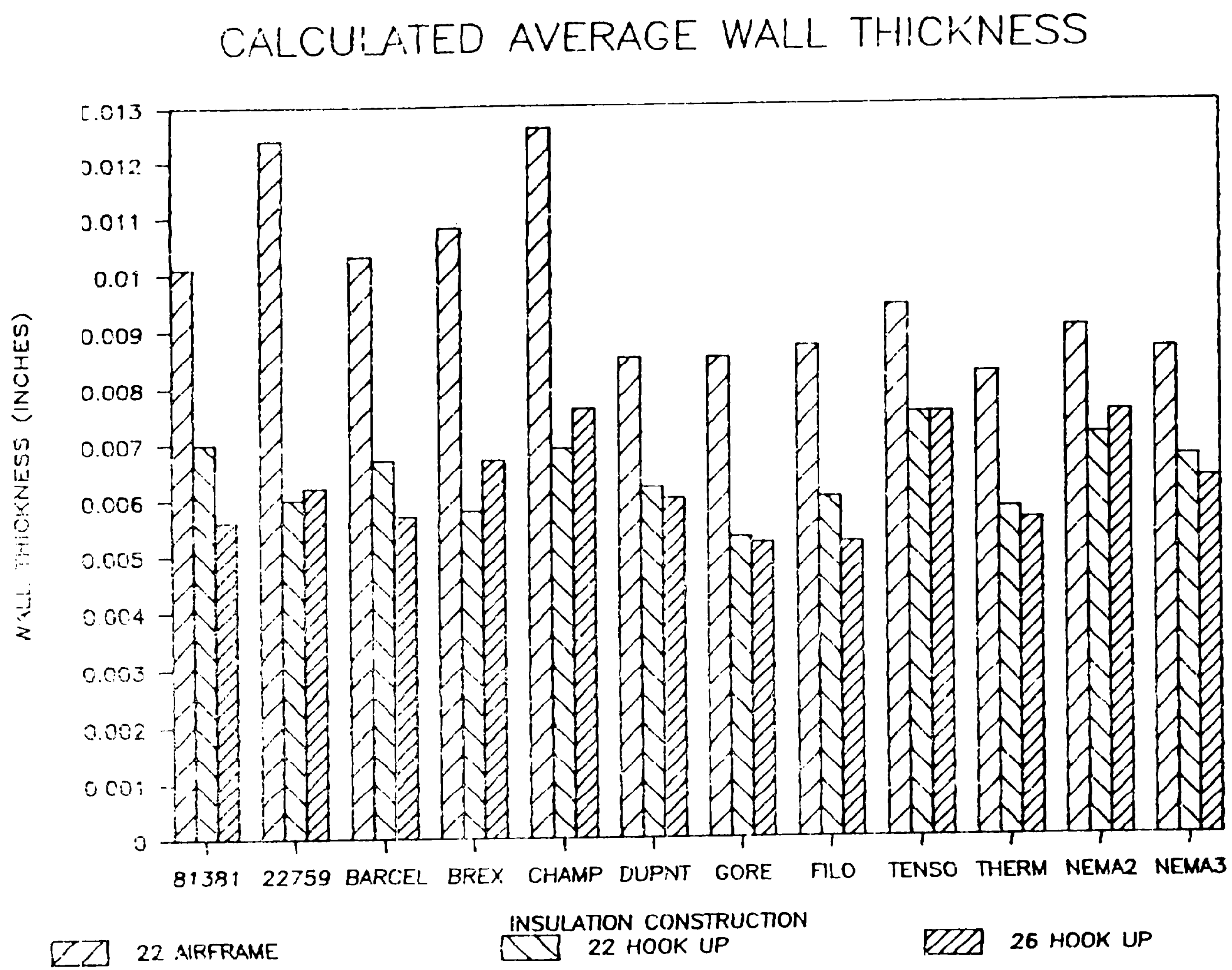


FIGURE 3.1 - CALCULATED AVERAGE WALL THICKNESS

3.3 COMBAT DAMAGE TESTS

3.3.1 DRY ARC RESISTANCE AND FAULT PROPAGATION.

3.3.1.1 Scope: The Dry Arc Resistance and Fault Propagation Test was used to measure the insulation's resistance to arcing and propagation of faults within a harness. This test also examined the damage to adjacent wires in the harness which were not powered or grounded.

3.3.1.2 Reference Procedure: The Dry Arc Resistance and Fault Propagation Test was performed in accordance with Method 301 of SAE AS4373. This test was performed using grounded back plates and a 100 volt dc Insulation Resistance Test instead of resetting circuit breakers.

3.3.1.3 Specimens: Three 20 wire harnesses were fabricated for each sample. The harnesses were 48±1 inches in length with black lacing cord (MIL-T-43435 type B) tied every two inches. The wires used to manufacture the harnesses were 22 gauge, 5.8 mil wall, hook up wire and 26 gauge, 5.8 mil wall, hook up wire. The locations of the wires within the harness are as shown in Figure 3.2, with wire gauge description and power application described in Table 3.13. The twisted pairs were similar to MCAIR's ST5M1247 specifications. The 22 gauge wires were constructed to have 12 to 18 twists per foot and the

26 gauge wires had 8 to 13 twists per foot. The harness common integrity wires formed a loop two inches beyond the shorting end of the harness. They were used to assess insulation damage in the arc. The shorting end of the harness consisted of a quarter inch of conductor exposed on each wire with the wire strands splayed. A single strand of 36 gauge wire was applied as a shorting path by tying it around the splayed ends. The last string tie of black lacing tape was placed a half inch from the end of the insulation at the shorting end of the harness. The powered end of the harness, connected to the circuit breaker panel, had a quarter inch of insulation removed from each wire and a spade terminal crimped on each conductor.

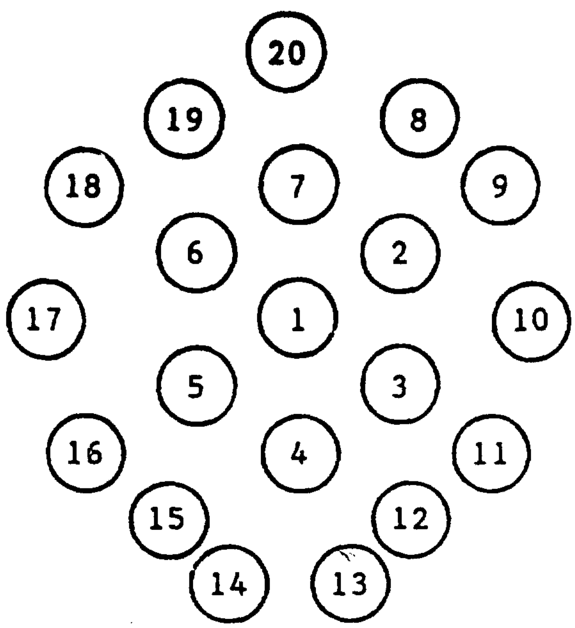


FIGURE 3.2 - WIRE LOCATIONS WITHIN THE HARNESS

TABLE 3.13 - WIRE LOCATION AND POWER TABLE

WIRE NO.	CONDUCTOR	POWER SOURCE
1	22 gauge, twisted pair	øA
2	22 gauge, twisted pair	øB
3	26 gauge, twisted pair	øC
4	26 gauge, twisted pair	øA
5	22 gauge	DC
6	22 gauge	AC Neutral
7	22 gauge	øB
8	22 gauge	øC
9	26 gauge	øC
10	22 gauge	DC Ground
11	26 gauge	øA
12	22 gauge	AC Neutral
13/17	22 gauge	Common Integrity
14/19	26 gauge	Common Integrity
15	26 gauge	DC Ground
16/20	22 gauge	Common Integrity
18	22 gauge	AC Neutral

3.3.1.4 Test Equipment: The circuit breaker panel consisted of MS3320, 7.5 amp, thermal circuit breakers for the 26 gauge powered conductors and MS3320, 15 amp, thermal circuit breakers for the 22 gauge powered conductors. The circuit breakers were tested prior to each Dry Arc Propagation Test to verify operational integrity. They were tested using dc current at a 200% overload and verified to trip within 1.5 to 40 seconds.

The ac power was supplied for the test by a F-15E aircraft generator. The generator is a constant speed drive system rated at 75,000 voltamperes. The Constant Speed Drive is manufactured by Sunstrand and the Generator is manufactured by Lucas. This is a 115 volt, three phase, 400 Hertz power system. The generator control unit, manufactured by Lucas, provides

undervoltage and overcurrent protection by monitoring a current transformer assembly. To trigger the undervoltage protection circuit, any single phase must drop to 95±5 volts for five seconds before the control unit will shut down the generator. It also monitors differential current and will shut down the generator instantaneously if a 40±5 amp difference is detected between any two phases. The generator is mounted to a 200 horse power General Electric motor.

The dc power was supplied by two transformer rectifier units (TRU) manufactured by Eldec. The TRU's are connected in parallel. Each are rated at 28 volts dc with a current rating of 150 amps. This provided a total dc current output of 300 amps. The test utilized a Hartman Electrical Manufacturing Power Contactor which was controlled by the generator control unit.

The Dry Arc Propagation Test was originated by closing a Jack and Heintz, 115 volt, 3 phase, power contactor to switch the ac power and a 28 volt dc Gaurdian Electric Mfg. Co. relay to switch the dc power. Total power was simultaneously applied to the harness via nine 12 gauge conductors when the AC and DC power contactors were energized.

A Beckman Megohmmeter (MD 78996) was used to conduct the insulation resistance measurements between each previously powered conductor and all other conductors tied common.

A Slaughter 103/105 High Voltage Leakage tester (MD 127358) was used to conduct the Voltage Withstand Test on the common integrity wires in the harness. The dielectric tester was preset to apply a 500 volt per second increase until the test voltage was achieved or a failure occurred.

Aluminum plates were utilized in the test setup to simulate grounded aircraft structure. A 0.125 inch thick 2 x 2 x 12 inch piece of aluminum angle was placed perpendicular to the specimen while a 0.0625 x 6 x 12 plate was placed parallel to the specimen. New plates were installed in the set-up for each test.

The test was videotaped using a standard VHS tape recorder and camera.

Photographs of the test setup and equipment are provided in Figures 3.3 through 3.6.

3.3.1.5 Test Procedure: The harness was placed in the test set up with the test end of the harness positioned at a distance of a half inch from the plate behind the harness and a quarter inch from the free end of the plate perpendicular to the harness. The common integrity wires were slightly bent because of proximity to the perpendicular plate.

Prior to application of power, all circuit breakers were closed, the generator was brought on line by closing the Hartman Main Line Contactor, and the ac and dc

contactors were closed simultaneously to apply power to the harness. The circuit breakers that tripped were recorded. The Dry Arc Propagation Test was recorded using a standard VHS video camera and recorder. Circuit breakers were not reset and power was removed from the harness, in conformance with SAE AS4373, Method 301.

After completion of the power application and prior to removing the harness from the test fixture, a 100 volt dc Insulation Resistance Test was performed on each of the powered conductors. The circuit breakers were opened and the circuit breaker panel disconnected from the generator. A Megohmmeter was used with the positive terminal connected to one of the powered conductors and all other powered conductors tied common to the return. A failure was defined as having a resistance of less than one megohm. This measurement was taken to give some indication of what may have occurred if the breakers had been reset and power reapplied.

After the specimens were removed from the test stand, the common integrity lines underwent a Voltage Withstand Test in accordance to Method 510 of SAE AS4373. The specimens were submerged in a 5% salt solution with 0.1% wetting agent (Aerosol OT) for a 4 hour soak period prior to electrification. A test voltage of 2500 volts at 60 Hertz was applied using a dielectric tester. The test voltage was applied to each common integrity wire for one minute to determine if insulation breakdown occurred. A

failure was defined as a specimen having a leakage current value exceeding 5 milliamps.

The insulation resistance measurements on M22759 specimens (107&108(A,B,C)), Barcel #1 specimens (112&113(A,B,C)), Brand Rex specimens (117&118(A,B,C)), and Champlain specimen (122&123(A)) were taken with the ground connections of the generator still connected to the chassis. The remaining measurements were taken with the generator ground lines removed from the circuit breaker panel.

3.3.1.6 Test Results: The post-test condition of the circuit breakers, evidence of arc propagation (significant conductor loss and or charred insulation), Voltage Withstand Test results on common integrity wires, and the post-test insulation resistance values are presented in Tables 3.14 through 3.16.

TABLE 3.14 - CIRCUIT BREAKER TEST RESULTS

SPOOL REF.	INSULATION CONSTRUCTION	TEST RUN	CIRCUIT BREAKER NUMBER 1	2	3	4	5	7	8	9	11
102&103	M81381	A	T	T	T	T	-	T	T	T	T
102&103	M81381	B	T	T	T	T	-	T	T	T	T
102&103	M81381	C	T	T	T	-	-	T	T	-	T
107&108	M22759	A	T	T	-	-	-	T	T	T	T
107&108	M22759	B	T	T	-	-	-	T	T	T	-
107&108	M22759	C	T	T	-	T	-	T	T	-	-
112&113	BARCEL #1	A	T	T	T	T	-	T	T	-	-
112&113	BARCEL #1	B	T	T	-	-	-	T	T	-	-
112&113	BARCEL #1	C	T	T	T	T	-	T	T	-	-
117&118	BRAND REX #1	A	T	T	-	T	-	T	T	-	-
117&118	BRAND REX #1	B	T	-	-	-	-	-	T	-	-
117&118	BRAND REX #1	C	T	T	-	-	-	T	T	-	-
122&123	CHAMPLAIN #1	A	T	T	-	-	-	T	T	-	-
122&123	CHAMPLAIN #1	B	T	T	-	T	-	T	T	T	-
122&123	CHAMPLAIN #1	C	T	T	T	T	-	T	T	T	-
127&128	DUPONT #1	A	T	T	-	T	-	T	T	T	-
127&128	DUPONT #1	B	T	T	T	-	-	T	T	-	-
127&128	DUPONT #1	C	T	T	T	T	-	T	T	T	T
132&133	GORE #3	A	T	T	-	-	-	T	T	-	T
132&133	GORE #3	B	T	-	-	-	-	T	T	-	-
132&133	GORE #3	C	T	T	-	-	-	-	T	-	-
137&138	FILOTEX	A	T	T	T	-	-	T	T	T	T
137&138	FILOTEX	B	T	T	T	T	-	T	T	T	-
137&138	FILOTEX	C	-	T	T	-	-	T	-	T	T
142&143	TENSOLITE #3	A	T	T	-	-	-	T	T	-	-
142&143	TENSOLITE #3	B	T	T	-	T	-	T	-	-	-
142&143	TENSOLITE #3	C	T	T	-	T	-	T	T	T	-
147&148	THERMATICS #3	A	T	T	-	-	-	T	-	T	-
147&148	THERMATICS #3	B	T	T	-	-	-	T	T	-	T
147&148	THERMATICS #3	C	T	T	T	-	-	T	T	-	-
152&153	NEMA #2	A	T	T	-	-	-	-	T	-	-
152&153	NEMA #2	B	T	T	-	T	-	T	T	T	-
152&153	NEMA #2	C	T	T	-	-	-	T	T	-	-
157&158	NEMA #3	A	T	T	T	-	-	T	T	T	-
157&158	NEMA #3	B	T	T	-	-	-	T	T	-	-
157&158	NEMA #3	C	T	T	T	-	-	T	T	-	-

T - C/B TRIPPED OPEN - = C/B REMAINED CLOSED

TABLE 3.15 - HARNESS TEST RESULTS

SPOOL REF.	INSULATION CONSTRUCTION	TEST RUN	EVIDENCE OF PROPAGATION	VOLTAGE WITHSTAND TEST ON COMMON INTEGRITY WIRES 13/17	14/19	16/20
102&103	M81381	A	YES	FAIL	FAIL	FAIL
102&103	M81381	B	YES	FAIL	FAIL	FAIL
102&103	M81381	C	YES	FAIL	FAIL	FAIL
107&108	M22759	A	NO	FAIL	FAIL	FAIL
107&108	M22759	B	NO	FAIL	FAIL	FAIL
107&108	M22759	C	NO	FAIL	FAIL	FAIL
112&113	BARCEL #1	A	NO	FAIL	FAIL	FAIL
112&113	BARCEL #1	B	NO	FAIL	FAIL	FAIL
112&113	BARCEL #1	C	NO	FAIL	FAIL	FAIL
117&118	BRAND REX #1	A	YES	FAIL	FAIL	FAIL
117&118	BRAND REX #1	B	YES	FAIL	FAIL	FAIL
117&118	BRAND REX #1	C	YES	FAIL	PASS	PASS
122&123	CHAMPLAIN #1	A	NO	FAIL	FAIL	FAIL
122&123	CHAMPLAIN #1	B	NO	FAIL	FAIL	FAIL
122&123	CHAMPLAIN #1	C	NO	FAIL	FAIL	FAIL
127&128	DUPONT #1	A	NO	FAIL	FAIL	PASS
127&128	DUPONT #1	B	NO	FAIL	FAIL	FAIL
127&128	DUPONT #1	C	NO	FAIL	FAIL	FAIL
132&133	GORE #3	A	NO	FAIL	FAIL	FAIL
132&133	GORE #3	B	NO	FAIL	FAIL	FAIL
132&133	GORE #3	C	NO	FAIL	FAIL	FAIL
137&138	FILOTEX	A	NO	FAIL	FAIL	FAIL
137&138	FILOTEX	B	NO	FAIL	FAIL	FAIL
137&138	FILOTEX	C	NO	FAIL	FAIL	FAIL
142&143	TENSOLITE #3	A	NO	PASS	PASS	PASS
142&143	TENSOLITE #3	B	NO	FAIL	FAIL	PASS
142&143	TENSOLITE #3	C	NO	PASS	PASS	PASS
147&148	THERMATICS #3	A	NO	FAIL	FAIL	FAIL
147&148	THERMATICS #3	B	NO	FAIL	FAIL	FAIL
147&148	THERMATICS #3	C	NO	FAIL	FAIL	FAIL
152&153	NEMA #2	A	NO	FAIL	FAIL	PASS
152&153	NEMA #2	B	NO	FAIL	FAIL	PASS
152&153	NEMA #2	C	NO	FAIL	FAIL	PASS
157&158	NEMA #3	A	NO	FAIL	FAIL	PASS
157&158	NEMA #3	B	NO	PASS	PASS	PASS
157&158	NEMA #3	C	NO	FAIL	FAIL	FAIL

TABLE 3.16 - INSULATION RESISTANCE TEST RESULTS

SPOOL REF.	INSULATION CONSTRUCTION	TEST RUN	POWERED CONDUCTOR NUMBER 1	2	3	4	5	7	8	9	11
102&103	M81381	A	O	S	S	S	S	S	S	S	S
102&103	M81381	B	O	S	S	S	S	S	S	O	S
102&103	M81381	C	S	S	S	O	S	S	S	O	S
107&108	M22759	A	O	O	O	O	O	O	O	O	O
107&108	M22759	B	O	O	O	O	O	O	O	O	O
107&108	M22759	C	O	O	O	O	O	O	O	O	O
112&113	BARCEL #1	A	O	O	O	O	O	O	O	O	O
112&113	BARCEL #1	B	S	O	O	O	S	O	O	O	O
112&113	BARCEL #1	C	S	S	O	O	O	O	O	O	O
117&118	BRAND REX #1	A	S	O	O	O	O	O	S	O	O
117&118	BRAND REX #1	B	O	O	O	O	S	S	O	O	O
117&118	BRAND REX #1	C	S	S	O	O	O	O	O	O	O
122&123	CHAMPLAIN #1	A	O	S	O	O	O	O	O	O	O
122&123	CHAMPLAIN #1	B	O	S	O	O	O	O	S	O	O
122&123	CHAMPLAIN #1	C	S	S	O	O	S	S	O	S	O
127&128	DUPONT #1	A	O	O	O	O	O	O	O	O	O
127&128	DUPONT #1	B	O	O	O	O	O	O	O	O	O
127&128	DUPONT #1	C	O	O	O	O	O	O	O	O	O
132&133	GORE #3	A	O	O	O	O	O	O	O	O	O
132&133	GORE #3	B	O	O	O	O	O	O	O	O	O
132&133	GORE #3	C	O	O	O	O	O	O	O	O	O
137&138	FILOTEX	A	S	O	S	O	O	O	O	O	O
137&138	FILOTEX	B	O	O	O	O	O	O	O	O	O
137&138	FILOTEX	C	O	O	O	O	O	O	O	O	O
142&143	TENSOLITE #3	A	O	O	O	O	O	O	O	O	O
142&143	TENSOLITE #3	B	O	O	O	O	O	O	O	O	O
142&143	TENSOLITE #3	C	O	O	O	O	O	O	O	O	O
147&148	THERMATICS #3	A	O	O	O	O	O	O	O	O	O
147&148	THERMATICS #3	B	O	O	O	O	O	O	S	O	O
147&148	THERMATICS #3	C	O	O	O	O	O	O	O	O	O
152&153	NEMA #2	A	O	O	O	O	O	O	O	O	O
152&153	NEMA #2	B	O	O	O	O	O	O	O	O	O
152&153	NEMA #2	C	O	O	O	O	O	O	O	O	O
157&158	NEMA #3	A	S	S	O	O	O	O	O	O	O
157&158	NEMA #3	B	O	O	O	O	O	O	O	O	O
157&158	NEMA #3	C	S	O	O	O	O	S	O	O	O

S = IR LESS THAN 1 MEGOHM   O = IR GREATER THAN 1 MEGOHM

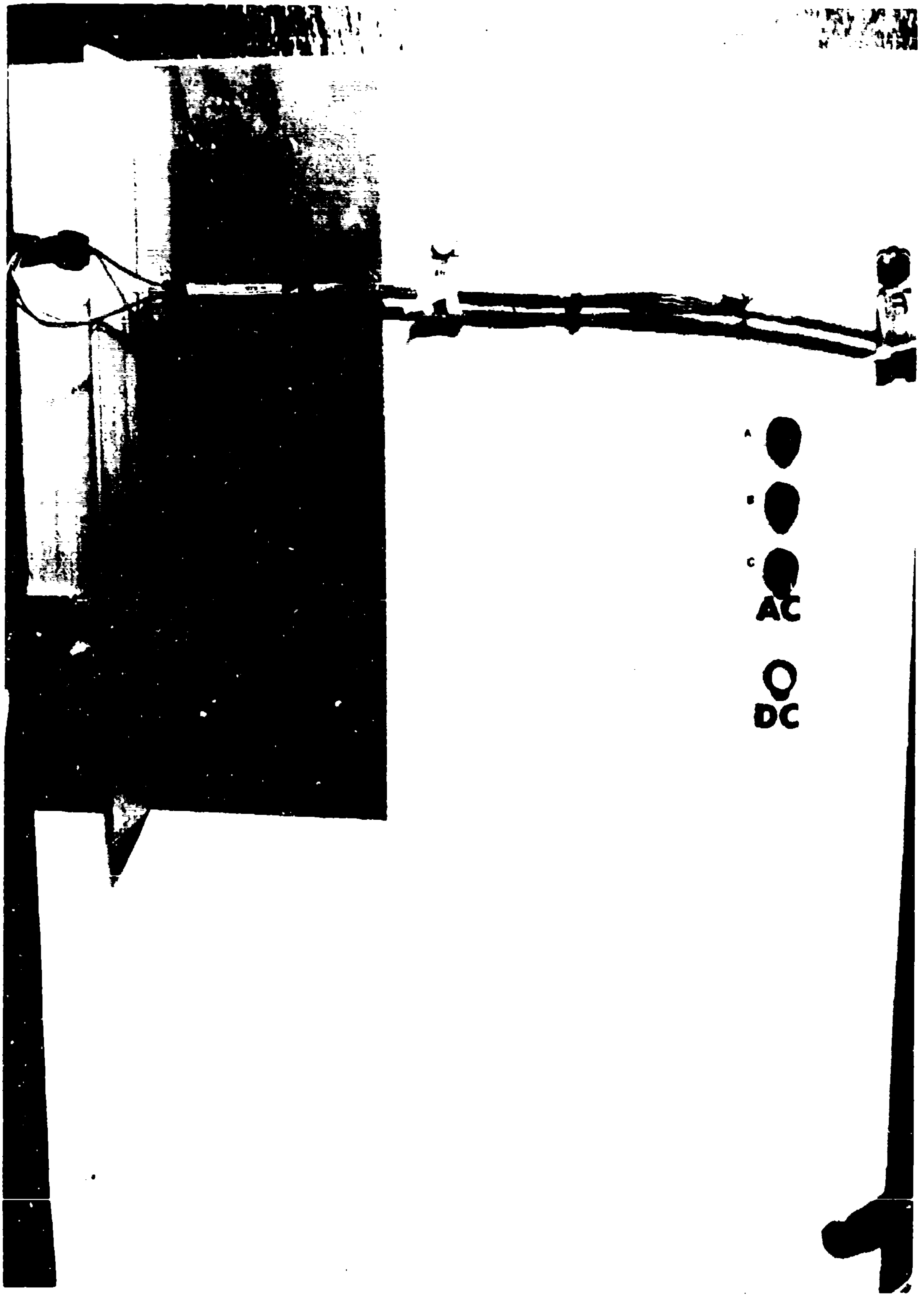


FIGURE 3.3 - TEST SPECIMEN IN SETUP

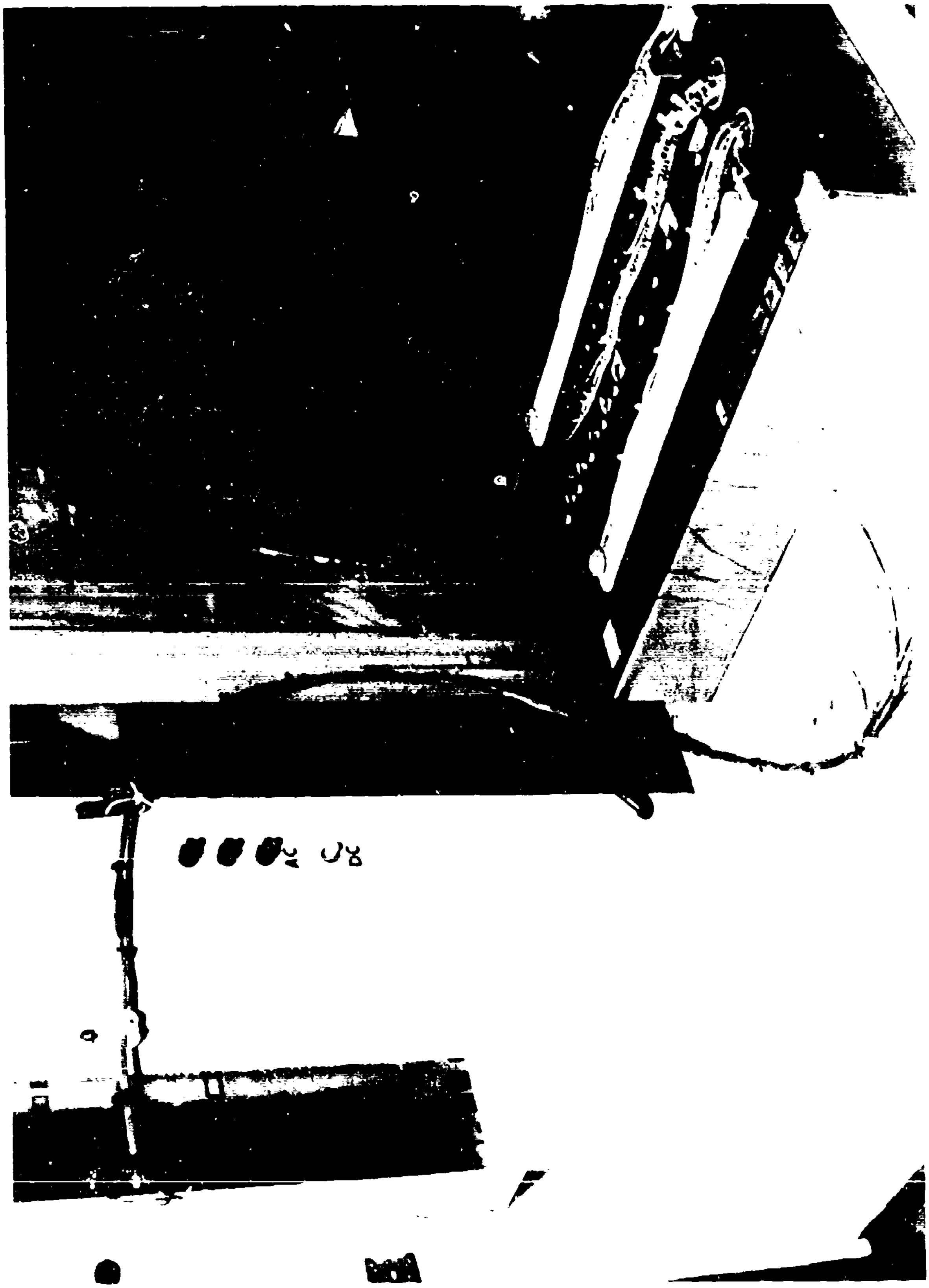


FIGURE [illegible] - TEST SPECIMEN AND CIRCUIT BREAKER CHASSIS

FIGURE 3.5 - AC DRY ARC RESISTANCE AND FAULT PROPAGATION TEST SETUP

FIGURE 3.6 - F-15E GENERATOR AND DRIVESTAND

3.4 CONDUCTOR TESTS

3.4.1 CONDUCTOR DIAMETER.

3.4.1.1 Scope: The Conductor Diameter Test was used to determine the average diameter of stranded conductors.

3.4.1.2 Reference Procedure: The Conductor Diameter Test was conducted according to Method 401 of SAE AS4373. The test was modified to acquire only two points of measurement on each specimen.

3.4.1.3. Specimens: The test utilized specimens from the Finished Wire Diameter Test. The test determined the average conductor diameter for 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. The specimens were 26 inches in length and cut from each end of the spool. A one inch segment of insulation was removed from both ends of the specimen using a Reon Cable Stripper so as not to damage or distort the conductor.

3.4.1.4. Test Equipment: A L.S. Starett Micrometer Caliper (MD 66-1-291) calibrated to 0.0003 inches was used to conduct the diameter measurements.

3.4.1.5. **Test Procedure:** The conductor diameter was measured with a micrometer at a point located a half inch from the each end of the conductor. Each point of measurement consisted of two micrometer readings, with the second reading 90° from the first reading. A total of four measurements were acquired from each specimen. The measurements from the two specimens were averaged together to acquire an average conductor diameter value for the sample.

The micrometer readings and the average conductor diameter were recorded.

3.4.1.6 **Test Results:** The minimum, maximum, and average conductor diameter values are presented in Tables 3.17 through 3.19. A graphical representation of the data is provided in Figure 3.7.

TABLE 3.17 - CONDUCTOR DIAMETER TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	CONDUCTOR DIAMETER (INCHES) MINIMUM	MAXIMUM	AVERAGE
101	M81381	0.0257	0.0279	0.0264
106	M22759	0.0236	0.0244	0.0238
111	BARCEL #1	0.0239	0.0249	0.0244
116	BRAND REX #1	0.0230	0.0237	0.0235
121	CHAMPLAIN #1	0.0237	0.0242	0.0240
126	DUPONT #1	0.0290	0.0292	0.0291
131	GORE #3	0.0303	0.0306	0.0304
136	FILOTEX	0.0273	0.0279	0.0276
141	TENSOLITE #3	0.0280	0.0291	0.0288
146	THERMATICS #3	0.0285	0.0293	0.0289
151	NEMA #2	0.0282	0.0289	0.0287
156	NEMA #3	0.0279	0.0289	0.0285

TABLE 3.18 - CONDUCTOR DIAMETER TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	CONDUCTOR DIAMETER (INCHES) MINIMUM	MAXIMUM	AVERAGE
102	M81381	0.0252	0.0280	0.0269
107	M22759	0.0277	0.0289	0.0284
112	BARCEL #1	0.0280	0.0289	0.0286
117	BRAND REX #1	0.0277	0.0288	0.0282
122	CHAMPLAIN #1	0.0280	0.0288	0.0283
127	DUPONT #1	0.0290	0.0295	0.0292
132	GORE #3	0.0302	0.0308	0.0306
137	FILOTEX	0.0272	0.0278	0.0274
142	TENSOLITE #3	0.0287	0.0291	0.0289
147	THERMATICS #3	0.0288	0.0291	0.0290
152	NEMA #2	0.0281	0.0287	0.0285
157	NEMA #3	0.0274	0.0286	0.0282

TABLE 3.19 - CONDUCTOR DIAMETER TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	CONDUCTOR DIAMETER (INCHES) MINIMUM	MAXIMUM	AVERAGE
103	M81381	0.0183	0.0188	0.0186
108	M22759	0.0181	0.0184	0.0182
113	BARCEL #1	0.0192	0.0195	0.0193
118	BRAND REX #1	0.0196	0.0206	0.0201
123	CHAMPLAIN #1	0.0170	0.0187	0.0178
128	DUPONT #1	0.0188	0.0190	0.0189
133	GORE #3	0.0186	0.0188	0.0187
138	FILOTEX	0.0186	0.0189	0.0188
143	TENSOLITE #3	0.0190	0.0191	0.0191
148	THERMATICS #3	0.0184	0.0189	0.0187
153	NEMA #2	0.0190	0.0191	0.0190
158	NEMA #3	0.0186	0.0190	0.0188

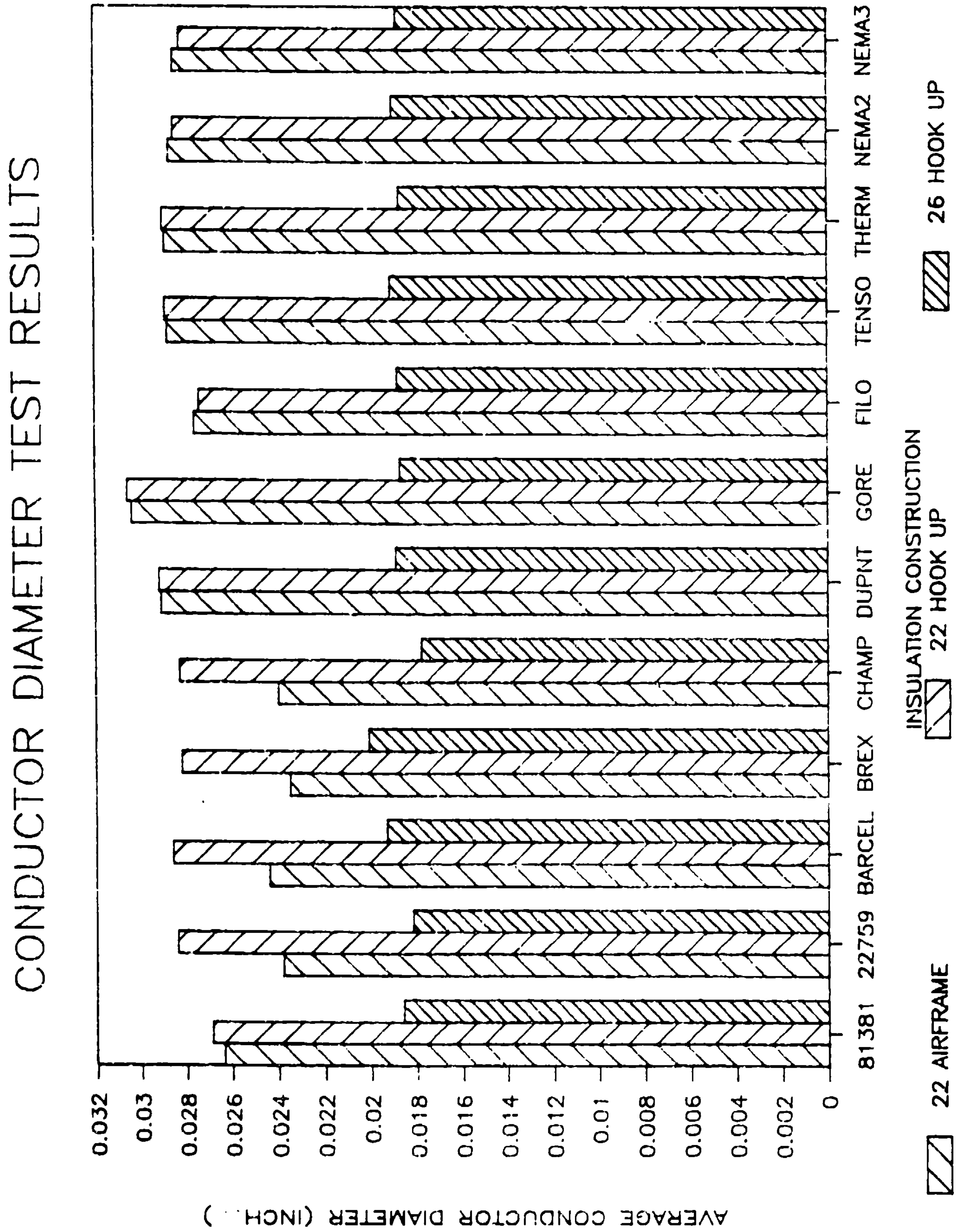


FIGURE 3.7 - CONDUCTOR DIAMETER TEST RESULTS

3.5 ELECTRICAL TESTS

3.5.1 IMPULSE DIELECTRIC.

3.5.1.1 Scope: The Impulse Dielectric Test describes a method for detecting defects in finished wire insulation using an impulse dielectric tester.

3.5.1.2 Reference Procedure: The Impulse Dielectric Test was performed according to the procedure outlined in Method 503 of SAE AS4373. Method 503 references ASTM D3032, Sections 13.3 through 13.6, for test equipment specifications and procedure.

3.5.1.3 Specimens: All initial wire samples received for the Air Force program underwent an impulse dielectric test. The constructions tested were 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire.

3.5.1.4 Test Equipment: A Kenrake Dielectric Tester was used to conduct the test in MCAIR's Manufacturing Receiving-Inspection area located in Building 250.

3.5.1.5 Test Procedure: All spools of wire initially received for the test program were subjected an impulse voltage of 8000 volts using the dielectric tester. The

potential was applied between the conductor and beads of the impulse test device. The dielectric failures were identified one inch before the faulted section and one inch after with an orange and black tiger tape. Wire splices were not considered as failures. The faulted sections were not used in any of the subsequent tests.

The length of the samples received, number of failures encountered, and a calculated value for failures per 1000 feet were recorded.

3.5.1.6 Test Results: The length of sample tested, number of failures encountered, and the calculated value for failures per 1000 feet are presented in Tables 3.20 through 3.22 with a graphical representation of the data provided in Figure 3.8.

TABLE 3.20 - IMPULSE DIELECTRIC TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	LENGTH (FEET)	NUMBER OF FAILURES	FAILURES PER 1000 FT.
101	M81381	3221	0	0.000
106	M22759	3124	0	0.000
111	BARCEL #1	1625	0	0.000
116	BRAND REX #1	980	0	0.000
121	CHAMPLAIN #1	2994	1	0.334
126	DUPONT #1	3273	0	0.000
131	GORE #3	3234	0	0.000
136	FILOTEX	1100	0	0.000
141	TENSOLITE #3	3267	4	1.224
146	THERMATICS #3	2873	0	0.000
151	NEMA #2	3011	0	0.000
156	NEMA #3	3376	0	0.000

TABLE 3.21 - IMPULSE DIELECTRIC TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	LENGTH (FEET)	NUMBER OF FAILURES	FAILURES PER 1000 FT.
102	M81381	3007	0	0.000
107	M22759	3454	0	0.000
112	BARCEL #1	3000	2	0.667
117	BRAND REX #1	1102	0	0.000
122	CHAMPLAIN #1	3210	0	0.000
127	DUPONT #1	3395	0	0.000
132	GORE #3	3595	0	0.000
137	FILOTEX	905	0	0.000
142	TENSOLITE #3	3740	0	0.000
147	THERMATICS #3	3368	1	0.297
152	NEMA #2	3517	0	0.000
157	NEMA #3	3569	0	0.000

TABLE 3.22 - IMPULSE DIELECTRIC TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	LENGTH (FEET)	NUMBER OF FAILURES	FAILURES PER 1000 FT.
103	M81381	3520	0	0.000
108	M22759	3402	0	0.000
113	BARCEL #1	3348	3	0.896
118	BRAND REX #1	1154	0	0.000
123	CHAMPLAIN #1	2982	0	0.000
128	DUPONT #1	3368	1	0.297
133	GORE #3	3005	0	0.000
138	FILOTEX	1041	0	0.000
143	TENSOLITE #3	3231	0	0.000
148	THERMATICS #3	3038	8	2.633
153	NEMA #2	3018	0	0.000
158	NEMA #3	2509	1	0.399

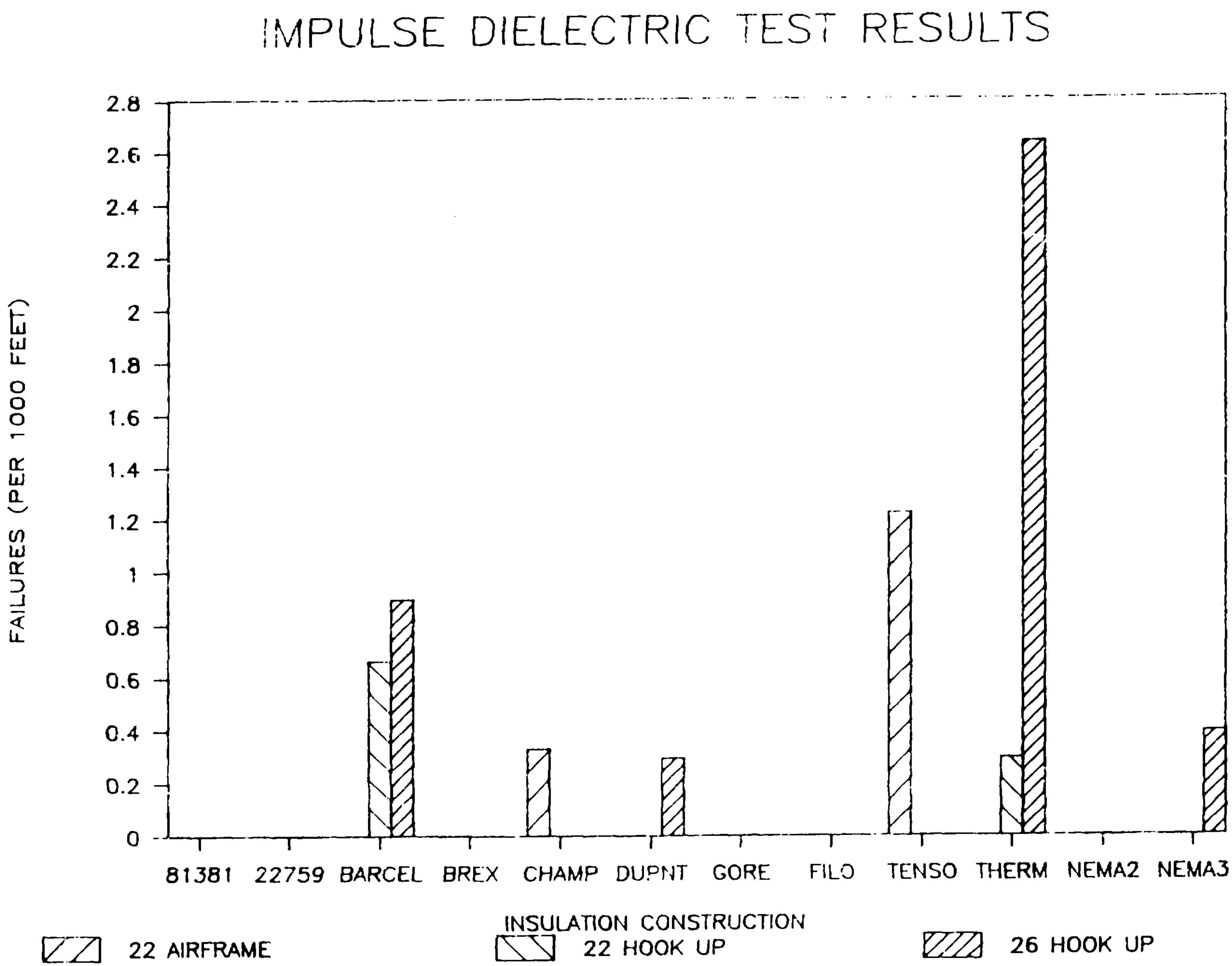


FIGURE 3.8 - IMPULSE DIELECTRIC TEST RESULTS

3.5.2 INSULATION RESISTANCE.

3.5.2.1 Scope: The Insulation Resistance Test was used to determine the insulation resistance of a finished wire sample that has been thermally aged for 1000 hours at 200°C (392°F). Insulation resistance is of interest in high impedance circuits and is a measure of quality control. Changes in insulation resistance may indicate deterioration of other properties.

3.5.2.2 Reference Procedure: The insulation resistance of a finished wire sample was determined according to Method 504 of SAE AS4373 which referenced ASTM D3032, Section 6. The test was conducted on specimens that were thermal aged for 1000 hours at 200°C (392°F).

3.5.2.3 Specimens: The Insulation Resistance Test was conducted on 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. One specimen of each sample was cut to a length of 26 feet and a half inch of insulation was stripped from both ends. The ends were twisted together and a #10 ring terminal was crimped on the conductors.

3.5.2.4 Test Equipment: A Beckman Megohmmeter (MD 78996) was used to determine the insulation resistance of the specimen at 500 volts dc.

The dielectric solution consisted of tap water with 0.1% wetting agent (Aerosol OT) added.

A photograph of the test setup is shown in Figure 3.10.

3.5.2.5 Test Procedure: The specimens were attached to a terminal strip and immersed to within approximately six inches from the insulation ends for a four hour soak. At the completion of the soak period, a potential of 500 volts dc was applied to the specimen. The positive terminal was attached to the terminal of the specimen and the negative was connected to an electrode immersed in the solution. The voltage was applied for one minute before the insulation resistance measurement was acquired. The measurement was converted to ohms-1000 feet by multiplying the acquired resistance value and measured length together and dividing that result by 1000. The actual insulation resistance measurement was recorded as well as the calculated value for a 1000 foot specimen.

3.5.2.6 Test Results: The Dupont specimens of 22 gauge, 8.6 mil wall, airframe wire (126) and the 22 gauge, 5.8 mil wall, hook up wire (127) test specimens were not 26 feet in length. Due to cracks in the insulation as a result of the thermal aging, the specimen length's were shortened to acquire an insulation resistance

measurement. The airframe specimen (126) used a length of 20 feet and the hook up wire specimen (127) used 10 feet. The NEMA #2, 22 gauge, 5.8 mil wall, hook up wire (152) specimen used a 16 foot specimen because of a cut in the insulation acquired during handling. The shorter lengths were taken into account in the calculation for a 1000 foot specimen.

The acquired insulation resistance measurement and the calculated insulation resistance for a 1000 foot specimen is presented in Tables 3.23 through 3.25 with graphical representation of the data provided in Figure 3.9.

TABLE 3.23 - INSULATION RESISTANCE TEST RESULTS ON THERMALLY AGED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	SPECIMEN LENGTH (FEET)	MEASURED INSULATION RESISTANCE (MEGOHMS)	CALCULATED INSULATION RESISTANCE - 1000 FT. (MEGOHMS)
101	M81381	25	3,000,000	75,000
106	M22759	25	6,000,000	150,000
111	BARCEL #1	25	1,200,000	30,000
116	BRAND REX #1	25	4,000,000	100,000
121	CHAMPLAIN #1	25	4,000,000	100,000
126	DUPONT #1	20	3,000,000	60,000
131	GORE #3	25	4,000,000	100,000
136	FILOTEX	25	30,000,000	750,000
141	TENSOLITE #3	25	10,000,000	250,000
146	THERMATICS #3	25	200,000	5,000
151	NEMA #2	25	8,000,000	200,000
156	NEMA #3	25	20,000,000	500,000

TABLE 3.24 - INSULATION RESISTANCE TEST RESULTS ON THERMALLY AGED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	SPECIMEN LENGTH (FEET)	MEASURED INSULATION RESISTANCE (MEGOHMS)	CALCULATED INSULATION RESISTANCE - 1000 FT. (MEGOHMS)
102	M81381	25	2,000,000	50,000
107	M22759	25	2,500,000	62,500
112	BARCEL #1	25	1,500,000	37,500
117	BRAND REX #1	25	1.1	0.0275
122	CHAMPLAIN #1	25	1,500,000	37,500
127	DUPONT #1	10	600,000	6,000
132	GORE #3	25	4,000,000	100,000
137	FILOTEX	25	15,000,000	375,000
142	TENSOLITE #3	25	8,000,000	200,000
147	THERMATICS #3	25	300,000	7,500
152	NEMA #2	16	8,000,000	200,000
157	NEMA #3	25	12,000,000	300,000

TABLE 3.25 - INSULATION RESISTANCE TEST RESULTS ON THERMALLY AGED, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	SPECIMEN LENGTH (FEET)	MEASURED INSULATION RESISTANCE (MEGOHMS)	CALCULATED INSULATION RESISTANCE - 1000 FT. (MEGOHMS)
103	M81381	25	4,000,000	100,000
108	M22759	25	7,000,000	175,000
113	BARCEL #1	25	2,000,000	50,000
118	BRAND REX #1	25	1,500,000	37,500
123	CHAMPLAIN #1	25	5,000,000	125,000
128	DUPONT #1	20	2,000,000	50,000
133	GORE #3	25	20,000,000	500,000
138	FILOTEX	25	20,000,000	500,000
143	TENSOLITE #3	25	20,000,000	500,000
148	THERMATICS #3	25	300,000	7,500
153	NEMA #2	25	12,000,000	300,000
158	NEMA #3	25	3,000,000	75,000

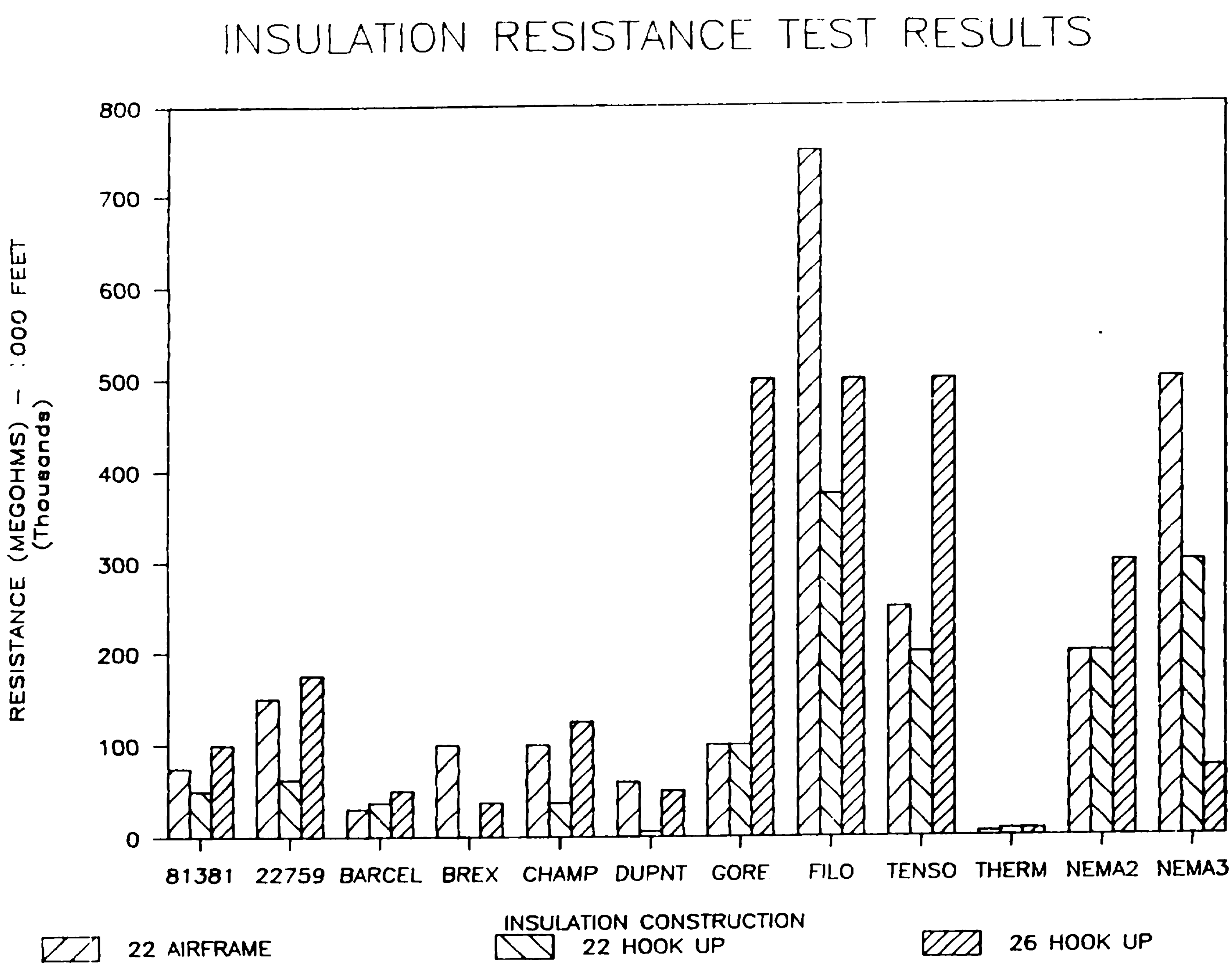


FIGURE 3.9 - INSULATION RESISTANCE TEST RESULTS

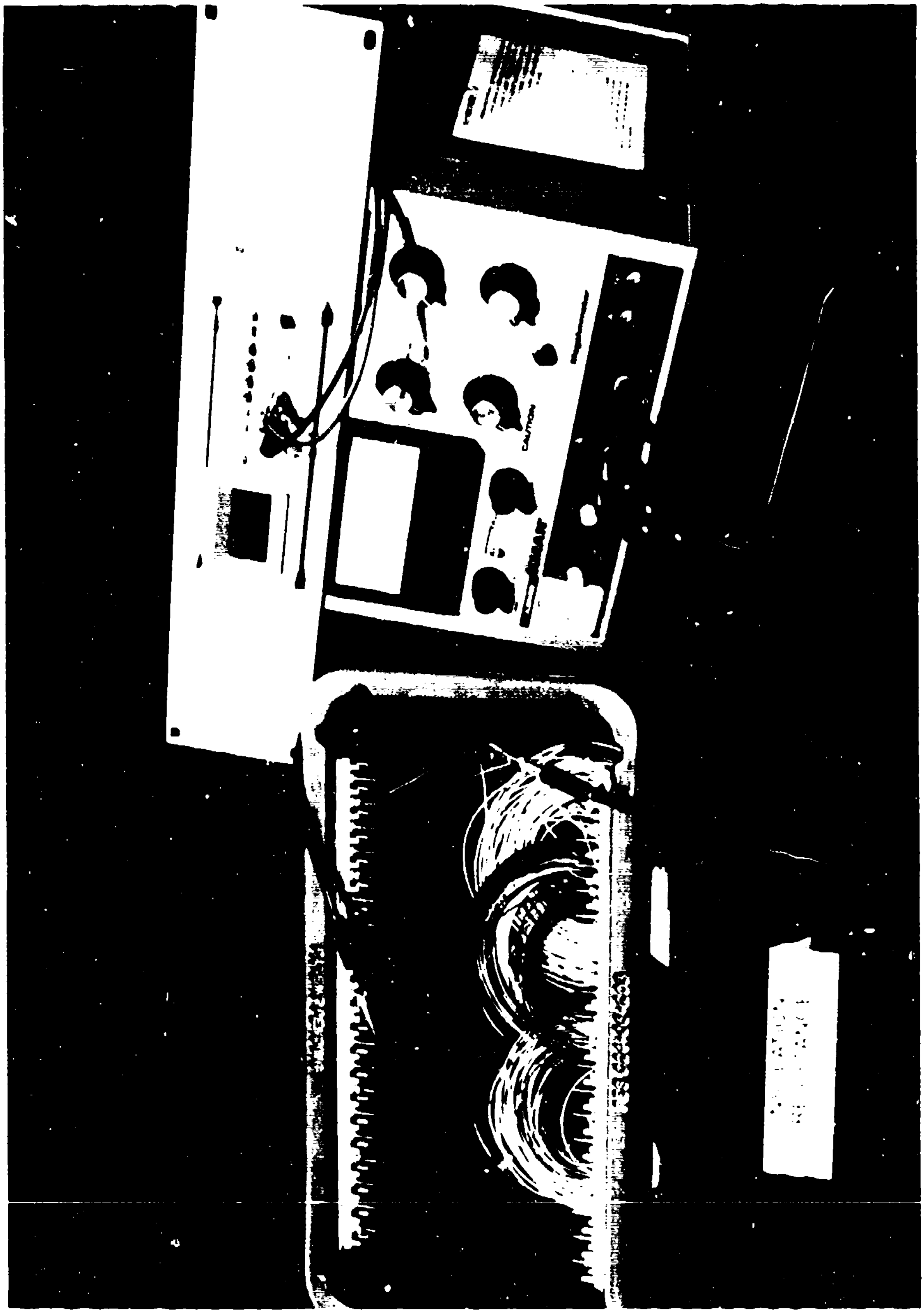


FIGURE 3.10 - INSULATION RESISTANCE TEST SETUP

3.5.3 SPARK TEST.

3.5.3.1 SPARK TEST ON FINISHED CABLE JACKET.

3.5.3.1.1 Scope: The Spark Test was used to detect defects in finished cable jacket constructions using a dielectric tester to test the cable jacket.

3.5.3.1.2 Reference Procedure: The Spark Test was performed using Method 503 of SAE AS4373 as a guide. Method 503 references ASTM D3032 sections 13.3 through 13.6 for test equipment specifications and procedure.

3.5.3.1.3 Specimens: All initial cable samples received for the test program underwent a spark test prior to any other testing. The constructions tested wero 22 and 26 gauge, two conductor, twisted, shielded and jacketed cable.

3.5.3.1.4 Test Equipment: A Kenrake Dielectric Tester was used to conduct the test in MCAIR's Manufacturing Receiving-Inspection area located in Building 250.

3.5.3.1.5 Test Procedure: The cable jackets were subjected to a spark test voltage of 1500 volts using a dielectric tester. The potential was applied between the specimen's shield and the beads of the spark test device. The

jacket failures were identified with an orange and black tiger tape one inch before the faulted section and one inch after. Cable splices were not considered as failures. The faulted sections were not used in any of the subsequent tests.

The length of the samples received, number of jacket failures encountered, and a calculated value for jacket failures per 1000 feet were recorded.

3.[illegible] Test Results: The number of failures detected, length of sample, and the calculated value for failures per 1000 feet is presented in Tables 3.26 through 3.27 with a graphical representation of data presented in Figure 3.11.

TABLE 3.26 - SPARK TEST RESULTS ON
22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	LENGTH (FEET)	NUMBER OF JACKET FAILURES	JACKET FAILURES PER 1000 FT.
104	M81381	2005	0	0.000
109	M22759	1305	0	0.000
114	BARCEL #1	645	0	0.000
119	BRAND REX #1	506	1	1.976
124	CHAMPLAIN #1	1479	0	0.000
129	DUPONT #1	1316	0	0.000
134	GORE #3	1550	7	4.516
144	TENSOLITE #3	1500	0	0.000
149	THERMATICS #3	395	0	0.000
154	NEMA #2	1795	0	0.000
159	NEMA #3	1497	0	0.000

TABLE 3.27 - SPARK TEST RESULTS ON
26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	LENGTH (FEET)	NUMBER OF JACKET FAILURES	JACKET FAILURES PER 1000 FT.
105	M81381	1512	0	0.000
110	M22759	3138	3	0.956
115	BARCEL #1	635	1	1.575
120	BRAND REX #1	502	2	3.984
125	CHAMPLAIN #1	1442	0	0.000
130	DUPONT #1	1056	0	0.000
135	GORE #3	1574	2	1.271
145	TENSOLITE #3	1414	0	0.000
150	THERMATICS #3	1124	1	0.890
155	NEMA #2	1430	1	0.699
160	NEMA #3	1114	0	0.000

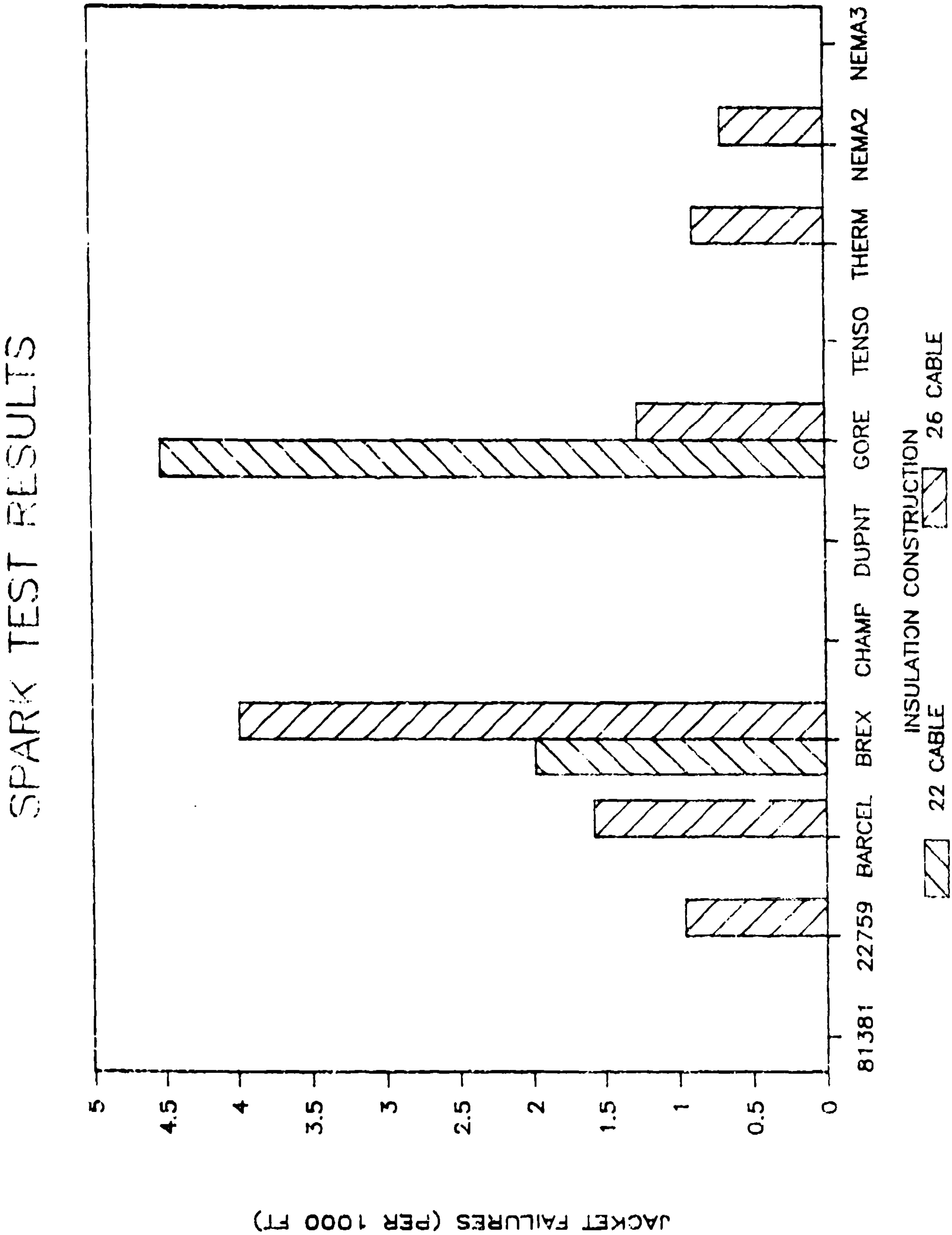


FIGURE 3.11 - SPARK TEST RESULTS

3.5.3.2 DRY DIELECTRIC TEST.

3.5.3.2.1 Scope: The Dry Dielectric Test was used to detect defects in finished cable construction using a dielectric tester to test the conductors to shield integrity.

3.5.3.2.2 Reference Procedure: The Dry Dielectric Test was performed using Method 503 of SAE AS4373 as a guide.

3.5.3.2.3 Specimens: All initial cable samples received for the test program underwent a dry dielectric test prior to any other testing. The constructions tested were 22 and 26 gauge, two conductor, twisted, shielded and jacketed cable.

3.5.3.2.4 Test Equipment: A Kenrako Dielectric Tester was used to conduct the test in MCAIR's Manufacturing Receiving-Inspection area located in Building 250.

3.5.3.2.5 Test Procedure: The cable samples underwent conductors to shield integrity test using 2500 volts. The results of this test disclosed whether a conductor to shield insulation breakdown occurred somewhere along the length of the sample.

The results of the conductors to shield integrity test were recorded either as a pass or fail. A passing sample is one where no breakdown between the conductors and

shield was observed. If a failure was detected, this meant there was a primary wire insulation breakdown somewhere along the length of the specimen.

3.5.3.2.6 Test Results: The pass or fail results of the dry dielectric tests are presented in Tables 3.28 through 3.29.

TABLE 3.28 - DRY DIELECTRIC TEST ON 22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	DRY DIELECTRIC TEST RESULTS
104	M81381	PASSED
109	M22759	PASSED
114	BARCEL #1	PASSED
119	BRAND REX #1	FAILED
124	CHAMPLAIN #1	PASSED
129	DUPONT #1	PASSED
134	GORE #3	PASSED
144	TENSOLITE #3	PASSED
149	THERMATICS #3	PASSED
154	NEMA #2	PASSED
159	NEMA #3	PASSED

TABLE 3.29 - DRY DIELECTRIC TEST ON 26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	DRY DIELECTRIC TEST RESULTS
105	M81381	PASSED
110	M22759	PASSED
115	BARCEL #1	PASSED
120	BRAND REX #1	PASSED
125	CHAMPLAIN #1	PASSED
140	DUPONT #1	PASSED
135	GORE #3	PASSED
145	TENSOLITE #3	PASSED
150	THERMATICS #3	PASSED
155	NEMA #2	PASSED
160	NEMA #3	PASSED

3.5.4 VOLTAGE WITHSTAND (WET DIELECTRIC).

3.5.4.1 Scope: The Voltage Withstand Test was used to determine the insulation integrity after being thermally aged for 1000 hours at 200°C (392°F).

3.5.4.2 Reference Procedure: The Voltage Withstand Test was conducted on thermally aged specimens in accordance with SAE AS4373, Method 510, which references ASTM D3032, Section 8. The specimens were thermally aged at 200°C (392°F) for 1000 hours.

3.5.4.3. Specimens: Specimens were constructed of 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Six specimens of each sample were cut to a length of 24 inches and a quarter inch of insulation was removed from each end. The conductors were twisted together and a #10 ring terminal was crimped on the conductors.

3.5.4.4 Test Equipment: A Slaughter Dielectric Tester (MD 78995) was used to conduct the dielectric test. The dielectric tester was preset to ramp to the test voltage at a rate of 500 volts per second. The test voltage used was 2,500 volts at 60 Hertz. The voltage was monitored by a Fluke 8050A Digital Multimeter (MD 011821) through a Fluke High Voltage Probe (MD 189698).

The dielectric solution consisted of a 5% sodium chloride (NaCl) solution with 0.1% wetting agent (Aerosol OT) added.

A photograph of the test setup and equipment is provided in Figure 3.13.

3.5.4.5 **Test Procedure:** The specimens were attached to a terminal strip and submerged to within two inches of the twisted ends in the dielectric solution for a four hour soak period prior to application of the test potential. At completion of the soak period, a test voltage of 2,500 volts at 60 Hertz was applied between the the conductor of the specimen and an electrode placed in the solution. The voltage was applied for one minute to determine if a voltage withstand breakdown had occurred. If a failure occurred, the time to failure was recorded (unless it was an immediate failure). A failure was defined as a specimen having a leakage current exceeding 5 milliamps. If no failure occurred, the maximum leakage current was recorded. After completion of the test, the specimens were rinsed in tap water and air dried before storage.

3.5.4.6 **Test Results:** The average leakage current for specimens passing the Voltage Withstand Test was recorded along with the average time to failure for specimens failing the test. The test results for the Voltage Withstand Test is presented in Tables 3.30 through 3.32

with a graphical representation of the data provided in Figure 3.12.

TABLE 3.30 - VOLTAGE WITHSTAND TEST RESULTS ON THERMALLY AGED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	VOLTAGE WITHSTAND TEST RESULTS (PASS/FAIL)	AVERAGE LEAKAGE CURRENT (MICRO-AMPS)	AVERAGE TIME TO FAILURE (SECONDS)
101	M81381	6 / 0	237	-------
106	M22759	6 / 0	193	-------
111	BARCEL #1	6 / 0	208	-------
116	BRAND REX #1	6 / 0	228	-------
121	CHAMPLAIN #1	6 / 0	180	-------
126	DUPONT #1	5 / 1	229	0
131	GORE #3	6 / 0	160	-------
136	FILOTEX	6 / 0	178	-------
141	TENSOLITE #3	6 / 0	163	-------
146	THERMATICS #3	6 / 0	290	-------
151	NEMA #2	6 / 0	168	-------
156	NEMA #3	6 / 0	201	-------

TABLE 3.31 - VOLTAGE WITHSTAND TEST RESULTS ON THERMALLY AGED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	VOLTAGE WITHSTAND TEST RESULTS (PASS/FAIL)	AVERAGE LEAKAGE CURRENT (MICRO-AMPS)	AVERAGE TIME TO FAILURE (SECONDS)
102	M81381	6 / 0	308	-------
107	M22759	6 / 0	245	-------
112	BARCEL #1	6 / 0	238	-------
117	BRAND REX #1	4 / 2	405	38
122	CHAMPLAIN #1	6 / 0	233	-------
127	DUPONT #1	3 / 3	258	0
132	GORE #3	6 / 0	212	-------
137	FILOTEX	6 / 0	206	-------
142	TENSOLITE #3	6 / 0	181	-------
147	THERMATICS #3	6 / 0	400	-------
152	NEMA #2	6 / 0	199	-------
157	NEMA #3	6 / 0	247	-------

TABLE 3.32 - VOLTAGE WITHSTAND TEST RESULTS ON THERMALLY AGED, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	VOLTAGE WITHSTAND TEST RESULTS (PASS/FAIL)	AVERAGE LEAKAGE CURRENT (MICRO-AMPS)	AVERAGE TIME TO FAILURE (SECONDS)
103	M81381	6 / 0	238	-------
108	M22759	6 / 0	196	-------
113	BARCEL #1	6 / 0	197	-------
118	BRAND REX #1	5 / 1	216	0
123	CHAMPLAIN #1	6 / 0	179	-------
128	DUPONT #1	5 / 1	188	0
133	GORE #3	6 / 0	151	-------
138	FILOTEX	6 / 0	178	-------
143	TENSOLITE #3	6 / 0	145	-------
148	THERMATICS #3	6 / 0	273	-------
153	NEMA #2	6 / 0	153	-------
158	NEMA #3	6 / 0	194	-------

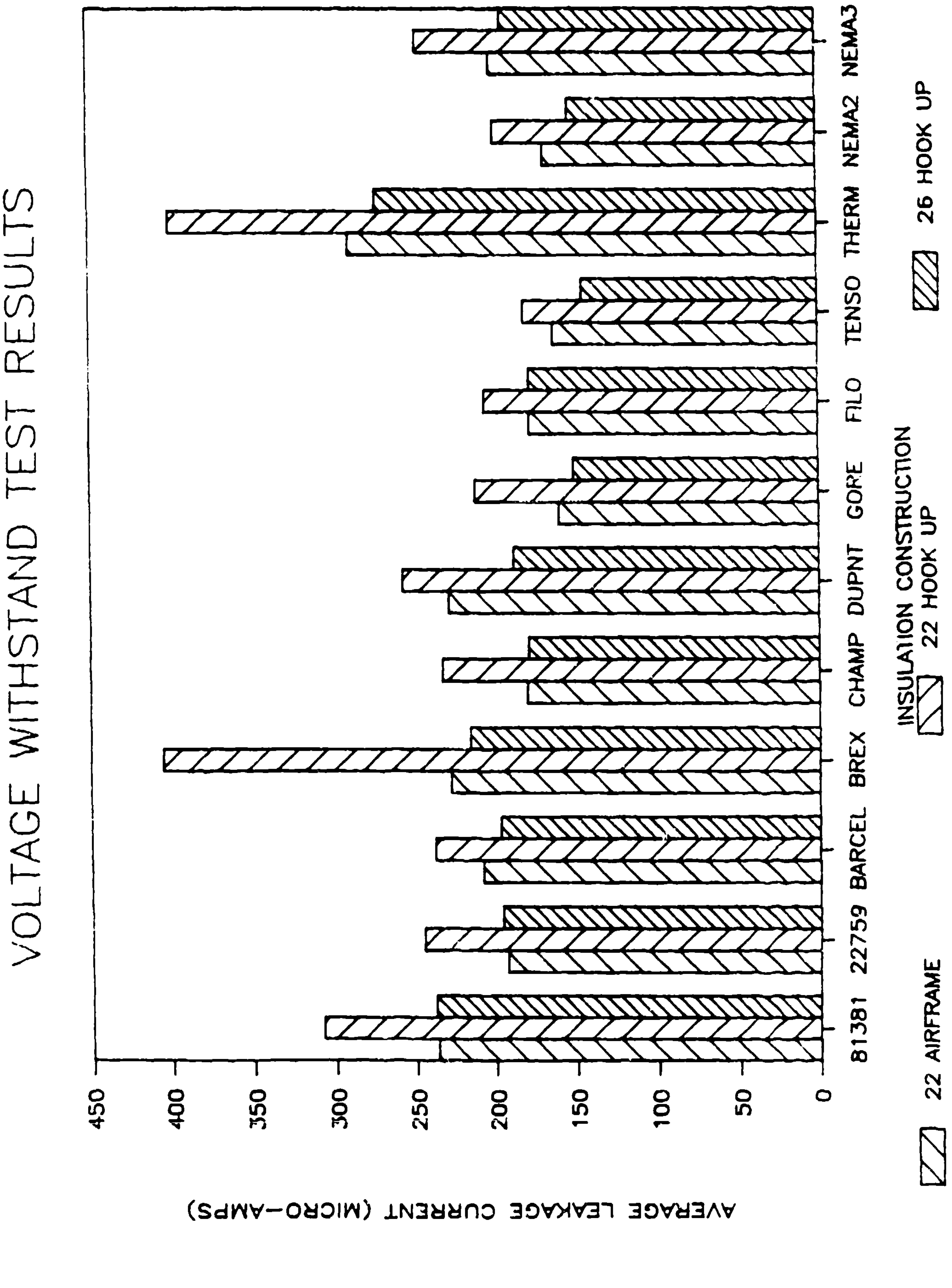


FIGURE 3.12 - VOLTAGE WITHSTAND TEST RESULTS

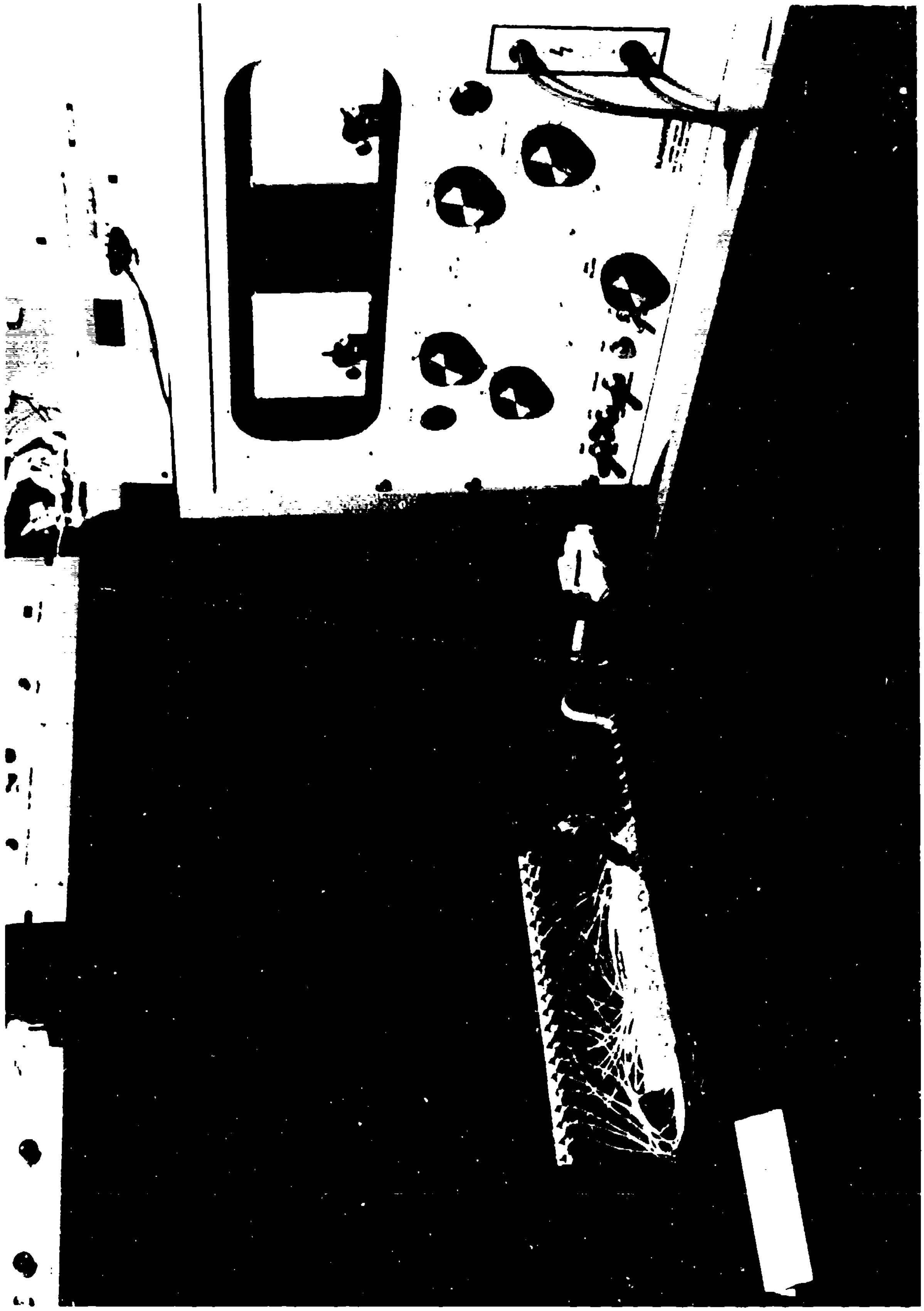


FIGURE 3.13 - VOLTAGE WITHSTAND TEST SETUP

3.6 ENVIRONMENTAL TESTS

3.6.1 FLUID IMMERSION.

3.6.1.1 Scope: The Fluid Immersion Test was used to determine the effects of various fluids on the insulation of the finished wire samples.

3.6.1.2. Reference Procedure: The Fluid Immersion Test was conducted according to Method 601 of SAE AS4373. This test also encompassed a Bend Test (Method 714) and a Voltage Withstand Test (Method 510). The fire resistant hydraulic fluid, SAE-AS-1241, and cleaning compound, MIL-C-25769, were replaced by MIL-H-83282 and MIL-C-87936, Type II, respectively.

3.6.1.3 Specimens: The Fluid Immersion Test was conducted on samples of 22 gauge, 5.8 mil wall, hook up wire. Three specimens were prepared for immersion into each fluid. The specimens were cut to a length of 24 inches with a quarter inch of insulation removed from the ends and #10 ring terminals crimped on both conductor ends.

3.6.1.4 Test Equipment: An L.S. Starett Micrometer Caliper (MD 66-1-291) calibrated to 0.0003 inches was used to conduct the diameter measurements.

A Blue M (MD B009296) forced draft air oven vented to

the outside was used for the elevated temperatures. The temperatures were monitored using a Fluke 2190A Digital Thermometer (MD 109893) with type T thermocouples in conjunction with a Fluke 2300A Scanner (MD E040001) and Fluke 2030A Printer for data acquisition.

A 2.0 inch diameter aluminum mandrel was assembled for use in the Bend Test.

A Slaughter 103/105 High Voltage Leakage tester (MD 127358) was used to conduct the Voltage Withstand Test. The dielectric tester was preset to apply a 500 volt per second increase until the test voltage of 2500 volts, 60 Hertz, was achieved or a failure occurred.

3.6.1.5 Test Procedure: The specimen initially underwent a pre-immersion diameter test conducted at two points on each specimen. The measurement points were at the 9 inch and 15 inch points on the specimen. Each point of measurement consisted of two micrometer readings, with the second reading 90° from the first. These four points of measurement were recorded to be compared with the same points after the immersion test to determine the amount of insulation swelling caused by fluid absorption.

The specimens were tied into a 2.0 inch diameter loop at the center of the specimen and the terminals attached to a terminal post in preparation for submersion. The specimens were placed in each fluid using the temperature and soak time specified in Table 3.33.

TABLE 3.33 - FLUID IMMERSION FLUID TABLE

	TEST FLUID	TEMPERATURE	IMMERSION TIME
(A)	LUBRICATING OIL (MIL-L-23699)	48°C TO 50°C	20 HOURS
(B)	HYDRAULIC FLUID (MIL-H-5606)	48°C TO 50°C	20 HOURS
(C)	ISPROPYL ALCOHOL (TT-I-735)	20°C TO 25°C	168 HOURS
(D)	TURBINE FUEL (MIL-T-5624)	20°C TO 25°C	168 HOURS
(E)	DEFROSTING FLUID UNDILUTED (MIL-A-8243)	48°C TO 50°C	20 HOURS
(F)	DEFROSTING FLUID DILUTED, 60:40 (MIL-A-8243)	48°C TO 50°C	20 HOURS
(G)	CLEANING COMPOUND (MIL-C-43616)	48°C TO 50°C	20 HOURS
(H)	METHYL ISOBUTYL KETONE (TT-M-268)	20°C TO 25°C	168 HOURS
(I)	HYDRAULIC FLUID (MIL-H-83282)	48°C TO 50°C	20 HOURS
(J)	LUBRICATING OIL (MIL-L-7808)	118°C TO 121°C	0.5 HOURS
(K)	CLEANING COMPOUND UNDILUTED (MIL-C-87936, Type II)	63°C TO 68°C	20 HOURS
(L)	CLEANING COMPOUND DILUTED 25:75 (MIL-C-87936, Type II)	63°C TO 68°C	20 HOURS
(M)	HYDROCARBON TYPE I (TT-S-735)	20°C TO 25°C	168 HOURS
(N)	HYDROCARBON TYPE II (TT-S-735)	20°C TO 25°C	168 HOURS
(O)	HYDROCARBON TYPE III (TT-S-735)	20°C TO 25°C	168 HOURS
(P)	HYDROCARBON TYPE VII (TT-S-735)	20°C TO 25°C	168 HOURS
(Q)	DIELECTRIC COOLANT FLUID	20°C TO 25°C	168 HOURS
(R)	TRICHLOROETHANE (MIL-T-81533)	20°C TO 25°C	168 HOURS
(S)	DUPONT FREON TMC	20°C TO 25°C	168 HOURS
(T)	AUTOMOTIVE GASOLINE (MIL-G-3056)	20°C TO 25°C	168 HOURS

Upon completion of the immersion sequence, the specimens were patted dry using cheesecloth and were air dried for a minimum of one hour before the post-immersion diameter measurements were taken at the same points previously utilized on the specimen. The values were compared to acquire a percentage change of the wire diameter. A failure was defined as a specimen's diameter changing by more than 5%.

Upon completion of post-immersion diameter measurements, all specimens underwent a Bend Test according to Method 714 of SAE AS4373. One end of the specimen was secured to a 2.0 inch mandrel and the other to a 1.0 pound weight to keep the specimen taut during wrapping. The specimen was wrapped at a rate of approximately four revolutions per minute for its full length in one direction and unwrapped at a similar rate. Then the specimen was wrapped in the opposite direction for its full length with the portion previously facing the mandrel, now facing away from the mandrel. The specimen was unwrapped and the entire cycle was repeated once more. After completion of the wrapping sequence, the insulation was inspected for cracking, delamination, or any other anomalies resulting from the test and they were recorded. If any anomalies were discovered on the specimen, it was identified as a failure.

The final test subjected the specimens to a Voltage Withstand Test per Method 510 of SAE AS4373, to detect

any voltage withstand breakdowns. The specimens were submerged to within two inches of their ends in a 5% salt solution with 0.1% wetting agent (Aerosol OT) added. The specimens were soaked in the solution for a period of four hours prior to application of the test potential. The test voltage of 2500 volts, 60 Hertz, was applied to the specimen for a period of one minute. If a leakage current value greater than 5.0 milliamps was detected, the specimen was identified as a failure. After completion of the test, the specimens were rinsed in tap water and air dried before storage. In some cases, cracks visually detected after the Bend Test were not deep enough to fail the Voltage Withstand Test.

3.6.1.6 Test Results: Two of the three specimens of Champlain immersed in fluid J, Lubricating Oil (MIL-L-7808), had some foreign debris observed inside the insulation, but were not identified as a failure because the anomaly was not a result of the test. The pre-immersion diameters, post-immersion diameters, Bend Test results, and the Voltage Withstand Test results are presented in Tables 3.34 through 3.53. The results of the Bend Test are described as follows: "P" = passed, "D" = delamination was observed, and "C" = cracks were discovered.

TABLE 3.34 - FLUID IMMERSION TEST RESULTS IN FLUID A - (MIL-L-23699) LUBRICATING OIL

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0410	0.0409	- 0.24 %	3/0/0	3/0
107	M22759	0.0409	0.0409	0.00 %	3/0/0	3/0
112	BARCEL #1	0.0419	0.0418	- 0.24 %	3/0/0	3/0
117	BRAND REX #1	0.0405	0.0405	0.00 %	3/0/0	3/0
122	CHAMPLAIN #1	0.0422	0.0423	+ 0.24 %	3/0/0	3/0
127	DUPONT #1	0.0422	0.0422	0.00 %	3/0/0	3/0
132	GORE #3	0.0412	0.0414	+ 0.49 %	3/0/0	3/0
137	FILOTEX	0.0396	0.0399	+ 0.76 %	3/0/0	3/0
142	TENSOLITE #3	0.0446	0.0445	- 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0407	0.0408	+ 0.25 %	3/0/0	3/0
152	NEMA #2	0.0428	0.0429	+ 0.23 %	3/0/0	3/0
157	NEMA #3	0.0420	0.0419	- 0.24 %	3/0/0	3/0

TABLE 3.35 - FLUID IMMERSION TEST RESULTS IN FLUID B - (MIL-H-5606) HYDRAULIC FLUID

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0406	0.0413	+ 1.72 %	3/0/0	3/0
107	M22759	0.0405	0.0407	+ 0.49 %	3/0/0	3/0
112	BARCEL #1	0.0417	0.0417	0.00 %	3/0/0	3/0
117	BRAND REX #1	0.0402	0.0401	- 0.25 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0423	0.0424	+ 0.24 %	3/0/0	3/0
127	DUPONT #1	0.0421	0.0422	+ 0.24 %	3/0/0	3/0
132	GORE #3	0.0413	0.0412	- 0.24 %	3/0/0	3/0
137	FILOTEX	0.0396	0.0398	+ 0.51 %	2/0/1	3/0
142	TENSOLITE #3	0.0448	0.0447	- 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0408	0.0408	0.00 %	1/1/1	3/0
152	NEMA #2	0.0432	0.0430	- 0.46 %	3/0/0	3/0
157	NEMA #3	0.0418	0.0418	0.00 %	3/0/0	3/0

TABLE 3.36 - FLUID IMMERSION TEST RESULTS IN FLUID C - (TT-I-735) ISOPROPYL ALCOHOL

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0413	0.0413	0.00 %	3/0/0	3/0
107	M22759	0.0407	0.0410	+ 0.74 %	3/0/0	3/0
112	BARCEL #1	0.0419	0.0417	- 0.48 %	3/0/0	3/0
117	BRAND REX #1	0.0406	0.0403	- 0.74 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0422	0.0422	0.00 %	3/0/0	3/0
127	DUPONT #1	0.0419	0.0421	+ 0.48 %	3/0/0	3/0
132	GORE #3	0.0412	0.0412	0.00 %	3/0/0	3/0
137	FILOTEX	0.0397	0.0397	0.00 %	3/0/0	3/0
142	TENSOLITE #3	0.0449	0.0448	- 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0408	0.0407	- 0.25 %	3/0/0	3/0
152	NEMA #2	0.0428	0.0429	+ 0.23 %	3/0/0	3/0
157	NEMA #3	0.0418	0.0420	+ 0.48 %	3/0/0	3/0

TABLE 3.37 - FLUID IMMERSION TEST RESULTS IN FLUID D - (MIL-T-5624) JP-4 TURBINE FUEL

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0410	0.0412	+ 0.49 %	3/0/0	3/0
107	M22759	0.0406	0.0408	+ 0.49 %	3/0/0	3/0
112	BARCEL #1	0.0416	0.0416	0.00 %	3/0/0	3/0
117	BRAND REX #1	0.0405	0.0405	0.00 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0418	0.0420	+ 0.48 %	3/0/0	3/0
127	DUPONT #1	0.0422	0.0422	0.00 %	3/0/0	3/0
132	GORE #3	0.0414	0.0412	- 0.48 %	3/0/0	3/0
137	FILOTEX	0.0397	0.0398	+ 0.25 %	3/0/0	3/0
142	TENSOLITE #3	0.0449	0.0449	0.00 %	3/0/0	3/0
147	THERMATICS #3	0.0408	0.0409	+ 0.25 %	3/0/0	3/0
152	NEMA #2	0.0429	0.0431	+ 0.47 %	3/0/0	3/0
157	NEMA #3	0.0417	0.0419	+ 0.48 %	3/0/0	3/0

TABLE 3.38 - FLUID IMMERSION TEST RESULTS IN
FLUID E - (MIL-A-8243) DEFROSTING FLUID, UNDILUTED

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0404	0.0412	+ 1.98 %	3/0/0	3/0
107	M22759	0.0404	0.0408	+ 0.99 %	3/0/0	3/0
112	BARCEL #1	0.0419	0.0417	- 0.48 %	3/0/0	3/0
117	BRAND REX #1	0.0405	0.0407	+ 0.49 %	0/3/0	2/1
122	CHAMPLAIN #1	0.0418	0.0420	+ 0.48 %	3/0/0	3/0
127	DUPONT #1	0.0421	0.0422	- 0.24 %	3/0/0	3/0
132	GORE #3	0.0411	0.0414	+ 0.73 %	3/0/0	3/0
137	FILOTEX	0.0396	0.0396	0.00 %	3/0/0	3/0
142	TENSOLITE #3	0.0447	0.0450	+ 0.67 %	3/0/0	3/0
147	THERMATICS #3	0.0406	0.0410	+ 0.99 %	3/0/0	3/0
152	NEMA #2	0.0424	0.0427	+ 0.71 %	2/0/1	3/0
157	NEMA #3	0.0415	0.0418	+ 0.72 %	3/0/0	3/0

TABLE 3.39 - FLUID IMMERSION TEST RESULTS IN
FLUID F - (MIL-A-8243) DEFROSTING FLUID, 60:40 (FLUID:WATER)

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0411	0.0414	+ 0.73 %	3/0/0	3/0
107	M22759	0.0406	0.0407	+ 0.25 %	3/0/0	3/0
112	BARCEL #1	0.0414	0.0416	+ 0.48 %	3/0/0	3/0
117	BRAND REX #1	0.0400	0.0404	+ 1.00 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0420	0.0421	+ 0.24 %	3/0/0	3/0
127	DUPONT #1	0.0421	0.0422	+ 0.24 %	3/0/0	3/0
132	GORE #3	0.0410	0.0413	+ 0.73 %	3/0/0	3/0
137	FILOTEX	0.0397	0.0398	+ 0.25 %	3/0/0	3/0
142	TENSOLITE #3	0.0447	0.0448	+ 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0408	0.0409	+ 0.25 %	3/0/0	3/0
152	NEMA #2	0.0428	0.0429	+ 0.23 %	3/0/0	3/0
157	NEMA #3	0.0419	0.0420	+ 0.24 %	3/0/0	3/0

TABLE 3.40 - FLUID IMMERSION TEST RESULTS IN FLUID G - (MIL-C-43616) CLEANING COMPOUND

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0412	0.0414	+ 0.49 %	3/0/0	3/0
107	M22759	0.0405	0.0406	+ 0.25 %	3/0/0	3/0
112	BARCEL #1	0.0417	0.0416	- 0.24 %	3/0/0	3/0
117	BRAND REX #1	0.0399	0.0401	+ 0.25 %	0/3/0	0/3
122	CHAMPLAIN #1	0.0420	0.0421	+ 0.24 %	3/0/0	3/0
127	DUPONT #1	0.0422	0.0423	+ 0.24 %	3/0/0	3/0
132	GORE #3	0.0411	0.0411	0.00 %	3/0/0	3/0
137	FILOTEX	0.0396	0.0398	+ 0.51 %	3/0/0	3/0
142	TENSOLITE #3	0.0446	0.0446	0.00 %	3/0/0	3/0
147	THERMATICS #3	0.0406	0.0407	+ 0.25 %	3/0/0	3/0
152	NEMA #2	0.0425	0.0426	+ 0.24 %	3/0/0	3/0
157	NEMA #3	0.0416	0.0419	+ 0.48 %	3/0/0	3/0

TABLE 3.41 - FLUID IMMERSION TEST RESULTS IN FLUID H - (TT-M-268) METHYL ISOBUTYL KETONE

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0410	0.0412	+ 0.49 %	3/0/0	3/0
107	M22759	0.0408	0.0409	+ 0.25 %	3/0/0	3/0
112	BARCEL #1	0.0418	0.0419	+ 0.24 %	3/0/0	3/0
117	BRAND REX #1	0.0401	0.0403	+ 0.50 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0420	0.0421	+ 0.24 %	3/0/0	3/0
127	DUPONT #1	0.0422	0.0422	0.00 %	2/0/1	3/0
132	GORE #3	0.0411	0.0411	0.00 %	3/0/0	3/0
137	FILOTEX	0.0396	0.0398	+ 0.50 %	3/0/0	3/0
142	TENSOLITE #3	0.0448	0.0449	+ 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0406	0.0408	+ 0.49 %	3/0/0	3/0
152	NEMA #2	0.0428	0.0429	+ 0.23 %	3/0/0	3/0
157	NEMA #3	0.0418	0.0420	+ 0.48 %	3/0/0	3/0

TABLE 3.42 - FLUID IMMERSION TEST RESULTS IN FLUID I - (MIL-H-83282) HYDRAULIC FLUID

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0411	0.0413	+ 0.49 %	3/0/0	3/0
107	M22759	0.0406	0.0408	+ 0.49 %	3/0/0	3/0
112	BARCEL #1	0.0416	0.0417	+ 0.24 %	3/0/0	3/0
117	BRAND REX #1	0.0406	0.0404	- 0.49 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0420	0.0420	0.00 %	3/0/0	3/0
127	DUPONT #1	0.0421	0.0422	+ 0.24 %	3/0/0	3/0
132	GORE #3	0.0411	0.0411	0.00 %	3/0/0	3/0
137	FILOTEX	0.0396	0.0396	0.00 %	3/0/0	3/0
142	TENSOLITE #3	0.0448	0.0449	+ 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0409	0.0409	0.00 %	3/0/0	3/0
152	NEMA #2	0.0427	0.0429	+ 0.47 %	3/0/0	3/0
157	NEMA #3	0.0416	0.0418	+ 0.48 %	3/0/0	3/0

TABLE 3.43 - FLUID IMMERSION TEST RESULTS IN FLUID J - (MIL-L-7808) LUBRICATING OIL

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0410	0.0410	0.00 %	3/0/0	3/0
107	M22759	0.0407	0.0410	+ 0.74 %	3/0/0	3/0
112	BARCEL #1	0.0417	0.0417	0.00 %	3/0/0	3/0
117	BRAND REX #1	0.0400	0.0404	+ 1.00 %	3/0/0	3/0
122	CHAMPLAIN #1	0.0421	0.0422	+ 0.24 %	3/0/0	3/0
127	DUPONT #1	0.0422	0.0423	+ 0.24 %	3/0/0	3/0
132	GORE #3	0.0413	0.0413	0.00 %	3/0/0	3/0
137	FILOTEX	0.0397	0.0396	- 0.25 %	3/0/0	3/0
142	TENSOLITE #3	0.0448	0.0449	+ 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0407	0.0408	+ 0.25 %	3/0/0	3/0
152	NEMA #2	0.0429	0.0430	+ 0.23 %	3/0/0	3/0
157	NEMA #3	0.0417	0.0419	+ 0.48 %	3/0/0	3/0

TABLE 3.44 - FLUID IMMERSION TEST RESULTS IN FLUID K - (MIL-C-87936, TYPE II) CLEANING COMPOUND, UNDILUTED

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0410	0.0432	+ 3.17 %	0/3/0	3/0
107	M22759	0.0409	0.0410	+ 0.24 %	3/0/0	3/0
112	BARCEL #1	0.0418	0.0417	- 0.24 %	3/0/0	3/0
117	BRAND REX #1	0.0404	0.0406	+ 0.50 %	0/3/0	0/3
122	CHAMPLAIN #1	0.0422	0.0425	+ 0.71 %	3/0/0	3/0
127	DUPONT #1	0.0421	0.042	+ 0.48 %	3/0/0	3/0
132	GORE #3	0.0410	0.0412	+ 0.49 %	3/0/0	3/0
137	FILOTEX	0.0394	0.0395	+ 0.25 %	0/0/3	1/2
142	TENSOLITE #3	0.0442	0.0448	+ 1.36 %	3/0/0	3/0
147	THERMATICS #3	0.0408	0.0407	- 0.25 %	3/0/0	3/0
152	NEMA #2	0.0427	0.0429	+ 0.47 %	3/0/0	3/0
157	NEMA #3	0.0417	0.0421	+ 0.96 %	3/0/0	3/0

TABLE 3.45 - FLUID IMMERSION TEST RESULTS IN FLUID L - (MIL-C-87936, TYPE II) CLEANING COMPOUND, 25:75 (FLUID:WATER)

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0409	0.0409	0.00 %	3/0/0	3/0
107	M22759	0.0408	0.0409	+ 0.25 %	3/0/0	3/0
112	BARCEL #1	0.0417	0.0418	+ 0.24 %	3/0/0	3/0
117	BRAND REX #1	0.0402	0.0399	- 0.75 %	0/3/0	0/3
122	CHAMPLAIN #1	0.0422	0.0424	+ 0.47 %	3/0/0	3/0
127	DUPONT #1	0.0421	0.0423	+ 0.48 %	3/0/0	3/0
132	GORE #3	0.0412	0.0412	0.00 %	3/0/0	3/0
137	FILOTEX	0.0397	0.0399	+ 0.50 %	3/0/0	3/0
142	TENSOLITE #3	0.0445	0.0445	0.00 %	3/0/0	3/0
147	THERMATICS #3	0.0409	0.0409	0.00 %	3/0/0	3/0
152	NEMA #2	0.0430	0.0431	+ 0.23 %	3/0/0	3/0
157	NEMA #3	0.0419	0.0420	+ 0.24 %	3/0/0	3/0

TABLE 3.46 - FLUID IMMERSION TEST RESULTS IN FLUID M - (TT-S-735) HYDROCARBON TYPE I

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	AVG. (3 SPECIMENS) DIAMETER (INCHES) POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0412	0.0412	0.00 %	3/0/0	3/0
107	M22759	0.0408	0.0407	- 0.25 %	3/0/0	3/0
112	BARCEL #1	0.0416	0.0415	- 0.24 %	3/0/0	3/0
117	BRAND REX #1	0.0399	0.0398	- 0.25 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0423	0.0424	+ 0.24 %	3/0/0	3/0
127	DUPONT #1	0.0421	0.0417	- 0.95 %	3/0/0	3/0
132	GORE #3	0.0411	0.0409	- 0.49 %	3/0/0	3/0
137	FILOTEX	0.0397	0.0397	0.00 %	3/0/0	3/0
142	TENSOLITE #3	0.0447	0.0445	- 0.45 %	3/0/0	3/0
147	THERMATICS #3	0.0408	0.0408	0.00 %	3/0/0	3/0
152	NEMA #2	0.0430	0.0428	- 0.47 %	3/0/0	3/0
157	NEMA #3	0.0417	0.0418	+ 0.24 %	3/0/0	3/0

TABLE 3.47 - FLUID IMMERSION TEST RESULTS IN FLUID N - (TT-S-735) HYDROCARBON TYPE II

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	AVG. (3 SPECIMENS) DIAMETER (INCHES) POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0410	0.0413	+ 0.73 %	3/0/0	3/0
107	M22759	0.0406	0.0409	+ 0.74 %	3/0/0	3/0
112	BARCEL #1	0.0417	0.0417	0.00 %	3/0/0	3/0
117	BRAND REX #1	0.0403	0.0404	+ 0.25 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0422	0.0424	+ 0.47 %	3/0/0	3/0
127	DUPONT #1	0.0420	0.0420	0.00 %	3/0/0	3/0
132	GORE #3	0.0412	0.0412	0.00 %	3/0/0	3/0
137	FILOTEX	0.0398	0.0398	0.00 %	3/0/0	3/0
142	TENSOLITE #3	0.0449	0.0451	+ 0.45 %	3/0/0	3/0
147	THERMATICS #3	0.0407	0.0408	+ 0.25 %	3/0/0	3/0
152	NEMA #2	0.0429	0.0430	+ 0.23 %	3/0/0	3/0
157	NEMA #3	0.0418	0.0420	+ 0.48 %	3/0/0	3/0

TABLE 3.48 - FLUID IMMERSION TEST RESULTS IN FLUID O - (TT-S-735) HYDROCARBON TYPE III

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0411	0.0413	+ 0.49 %	3/0/0	3/0
107	M22759	0.0405	0.0406	+ 0.25 %	3/0/0	3/0
112	BARCEL #1	0.0419	0.0421	+ 0.48 %	3/0/0	3/0
117	BRAND REX #1	0.0401	0.0404	+ 0.75 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0421	0.0422	+ 0.24 %	3/0/0	3/0
127	DUPONT #1	0.0423	0.0424	+ 0.24 %	3/0/0	3/0
132	GORE #3	0.0410	0.0409	- 0.24 %	2/0/1	2/1
137	FILOTEX	0.0397	0.0399	+ 0.50 %	3/0/0	3/0
142	TENSOLITE #3	0.0452	0.0453	+ 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0406	0.0407	+ 0.25 %	3/0/0	3/0
152	NEMA #2	0.0427	0.0427	0.00 %	3/0/0	3/0
157	NEMA #3	0.0419	0.0419	0.00 %	3/0/0	3/0

TABLE 3.49 - FLUID IMMERSION TEST RESULTS IN FLUID P - (TT-S-735) HYDROCARBON TYPE VII

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0410	0.0411	+ 0.24 %	3/0/0	3/0
107	M22759	0.0408	0.0409	+ 0.25 %	3/0/0	3/0
112	BARCEL #1	0.0418	0.0418	0.00 %	3/0/0	3/0
117	BRAND REX #1	0.0400	0.0401	+ 0.25 %	3/0/0	3/0
122	CHAMPLAIN #1	0.0421	0.0421	0.00 %	3/0/0	3/0
127	DUPONT #1	0.0422	0.0422	0.00 %	3/0/0	3/0
132	GORE #3	0.0414	0.0412	- 0.48 %	3/0/0	3/0
137	FILOTEX	0.0398	0.0398	0.00 %	3/0/0	3/0
142	TENSOLITE #3	0.0448	0.0458	+ 2.23 %	3/0/0	3/0
147	THERMATICS #3	0.0407	0.0407	0.00 %	3/0/0	3/0
152	NEMA #2	0.0428	0.0427	- 0.23 %	3/0/0	3/0
157	NEMA #3	0.0419	0.0419	0.00 %	3/0/0	3/0

TABLE 3.50 - FLUID IMMERSION TEST RESULTS IN FLUID Q - DIELECTRIC COOLANT FLUID

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0411	0.0413	+ 0.49 %	3/0/0	3/0
107	M22759	0.0408	0.0408	0.00 %	3/0/0	3/0
112	BARCEL #1	0.0418	0.0419	+ 0.24 %	3/0/0	3/0
117	BRAND REX #1	0.0400	0.0401	+ 0.25 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0422	0.0422	0.00 %	3/0/0	3/0
127	DUPONT #1	0.0422	0.0423	+ 0.24 %	3/0/0	3/0
132	GORE #3	0.0412	0.0411	- 0.24 %	3/0/0	3/0
137	FILOTEX	0.0395	0.0395	0.00 %	3/0/0	3/0
142	TENSOLITE #3	0.0454	0.0450	- 0.88 %	3/0/0	3/0
147	THERMATICS #3	0.0410	0.0410	0.00 %	3/0/0	3/0
152	NEMA #2	0.0427	0.0427	0.00 %	3/0/0	3/0
157	NEMA #3	0.0418	0.0419	+ 0.24 %	3/0/0	3/0

TABLE 3.51 - FLUID IMMERSION TEST RESULTS IN FLUID R - (MIL-T-81533) 1,1,1 TRICHLOROETHANE

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0410	0.0412	+ 0.49 %	3/0/0	3/0
107	M22759	0.0406	0.0408	+ 0.49 %	3/0/0	3/0
112	BARCEL #1	0.0420	0.0421	+ 0.24 %	3/0/0	3/0
117	BRAND REX #1	0.0408	0.0407	- 0.24 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0411	0.0424	+ 3.16 %	3/0/0	3/0
127	DUPONT #1	0.0425	0.0425	0.00 %	3/0/0	3/0
132	GORE #3	0.0414	0.0413	- 0.24 %	3/0/0	3/0
137	FILOTEX	0.0396	0.0397	+ 0.25 %	3/0/0	3/0
142	TENSOLITE #3	0.0452	0.0451	- 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0409	0.0409	0.00 %	3/0/0	3/0
152	NEMA #2	0.0429	0.0428	- 0.23 %	3/0/0	3/0
157	NEMA #3	0.0418	0.0419	+ 0.24 %	3/0/0	3/0

TABLE 3.52 - FLUID IMMERSION TEST RESULTS IN FLUID S - DUPONT FREON TMC

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0412	0.0417	+ 1.21 %	3/0/0	3/0
107	M22759	0.0404	0.0407	+ 0.74 %	3/0/0	3/0
112	BARCEL #1	0.0418	0.0421	+ 0.72 %	3/0/0	3/0
117	BRAND REX #1	0.0403	0.0405	+ 0.50 %	0/3/0	3/0
122	CHAMPLAIN #1	0.0423	0.0426	+ 0.71 %	3/0/0	3/0
127	DUPONT #1	0.0422	0.0426	+ 0.95 %	3/0/0	3/0
132	GORE #3	0.0413	0.0413	0.00 %	3/0/0	3/0
137	FILOTEX	0.0397	0.0403	+ 1.51 %	3/0/0	3/0
142	TENSOLITE #3	0.0452	0.0453	+ 0.22 %	3/0/0	3/0
147	THERMATICS #3	0.0410	0.0411	+ 0.24 %	3/0/0	3/0
152	NEMA #2	0.0427	0.0428	+ 0.23 %	3/0/0	3/0
157	NEMA #3	0.0420	0.0425	+ 1.19 %	3/0/0	3/0

TABLE 3.53 - FLUID IMMERSION TEST RESULTS IN FLUID T - (MIL-G-3056) AUTOMOTIVE GASOLINE

SPOOL REF.	INSULATION CONSTRUCTION	AVG. (3 SPECIMENS) DIAMETER (INCHES) PRE-IMMERSION	POST-IMMERSION	AVERAGE DIAMETER PERCENT CHANGE	BEND TEST RESULTS (P/D/C)	VOLTAGE WITHSTAND RESULTS (P/F)
102	M81381	0.0413	0.0412	- 0.24 %	3/0/0	3/0
107	M22759	0.0407	0.0408	+ 0.25 %	3/0/0	3/0
112	BARCEL #1	0.0418	0.0418	0.00 %	3/0/0	3/0
117	BRAND REX #1	0.0404	0.0403	- 0.25 %	0/3/0	1/2
122	CHAMPLAIN #1	0.0422	0.0423	+ 0.24 %	3/0/0	3/0
127	DUPONT #1	0.0422	0.0423	+ 0.24 %	3/0/0	3/0
132	GORE #3	0.0413	0.0412	- 0.24 %	3/0/0	3/0
137	FILOTEX	0.0398	0.0397	- 0.25 %	3/0/0	3/0
142	TENSOLITE #3	0.0450	0.0450	0.00 %	3/0/0	3/0
147	THERMATICS #3	0.0408	0.0409	+ 0.25 %	3/0/0	3/0
152	NEMA #2	0.0429	0.0429	0.00 %	3/0/0	3/0
157	NEMA #3	0.0419	0.0420	+ 0.24 %	3/0/0	3/0

3.7 MECHANICAL TESTS

NOTE: All screening mechanical tests, except Stiffness and Springback, used wire that had been thermally aged at 200°C (392°F) for 1000 hours to simulate long term aircraft usage and identify performance capability subsequent to the simulated exposure.

3.7.1 ABRASION.

3.7.1.1 Scope: The Abrasion Test was used to provide a relative wear abrasion resistance evaluation of wire insulations thermally aged for 1000 hours at 200°C (392°F).

3.7.1.2 Reference Procedure: The Abrasion Test was conducted according to Method 701 of SAE AS4373 which refers to an unreleased draft procedure of ASTM D09.16. The test was conducted at room ambient and 150°C (302°F) on thermally aged specimens.

3.7.1.3 Specimens: The Wear Abrasion Test was conducted on conditioned samples of 22 gauge, 8.6 mil wall, airframe wire and 22 gauge, 5.8 mil wall, hook up wire that were thermally aged for 1000 hours at 200°C (392°F). Four thermally aged specimens of each sample were cut to a length of 12 inches. A quarter inch of insulation was

removed from both ends and #10 ring terminals were crimped onto the conductor ends. The four specimens were placed on the holding block at 0°, 90°, 180°, and 270° from the natural curvature (reel set) of the specimen.

3.7.1.4 Test Equipment: The abrading tool consisted of a 0.020 inch diameter tungsten carbide rod silver soldered to a mounting fixture. The tool was secured to the two support arms which were counterbalanced to give a tool force of 10 grams when no weights were applied. The test fixture had the ability to be loaded with weights centered above the abrading tool. The arms were attached to an ac motor that drove the tools along a one inch linear path on the specimen at a rate of 60 cycles per minute.

The specimen holding fixture was a block of aluminum which had four 0.026 inch deep "V" grooves for the test specimens. The specimens were placed in the grooves with 1.1 pound weights attached to the ring terminals to apply tension. The specimens were centered and clamped into place at both ends of the aluminum test block.

A Delta Design oven (MD 058174) was used at the elevated temperature of 150°C (302°F) with a Fluke Datalogger (MD 84509) to monitor the temperature with a type J thermocouple.

Photographs of the test setup at room temperature and 150°C (302°F) are provided in Figures 3.18 through 3.21.

3.7.1.5 Test Procedure: The Abrasion Test was conducted on two specimens simultaneously until the abrading tool made electrical contact with the wire conductor. The abrading machine was setup to automatically stop when either of the test specimen's insulation was penetrated. The drive rod on the first wire to fail was raised and locked in the up position to prevent rubbing the abrasion tool on the conductor while the remaining wire was tested to failure.

A calibration test was made at room temperature on each abrasion tool prior to testing each sample of wire. A 3 mil thick sheet of Kapton polyimide tape was wrapped one layer thick around a 0.375 inch diameter steel rod one layer thick. The abrasion tool rubbed against the Kapton polyimide tape with a two pound weight until continuity was made with the steel rod. The test was conducted at three different spots on the Kapton polyimide tape for each abrasion tool.

The test began with the drive arms locked in the up position and the holding block was placed under the abrading tools. A Silicone pad was placed over the specimens and the arms were lowered onto the pad. The pad was used to prevent the abrasion tool from dropping onto the wire when the drive arm locking pin was removed. The tool was raised off the pad, the pad was removed, and the tool was gently lowered onto the test wire. The test was started and ran until both specimens failed. Both

drive rods were raised and the weight on the tool was changed. The holding fixture was moved forward approximately two inches to an untested spot on the specimen and the test was repeated until data had been collected on one, two, and three pound weights. Both drive rods were raised and locked in the up position so that the holding fixture could be repositioned to test the remaining two specimens.

The same procedure was used to test the specimens at ambient as well at 150°C (302°F) except that the temperature stabilization times were not necessary at ambient. The test at the elevated temperature was conducted in a forced draft air oven vented to the outside. A temperature stabilization time of one hour minimum was required for the block and specimens. The test started after the block achieved the desired temperature of 150°C (302°F). After every subsequent opening of the chamber, the test began one to two minutes after the block recovered to within 2°C of the test temperature.

The number of cycles to failure and the average number of cycles to failure were recorded.

3.7.1.6 Test Results: The average number of cycles to failure are presented in Tables 3.54 through 3.57 with graphical representation of the data provided in Figures 3.14 through 3.17. Zero cycles for the elevated temperature tests indicate that the abrasion tool cut through the insulation as soon as the abrading tool was placed on the wire with the corresponding weight.

TABLE 3.54 - ABRASION TEST RESULTS ON THERMALLY AGED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 23°C (73°F)

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES (1 POUND)	AVERAGE NUMBER OF CYCLES (2 POUND)	AVERAGE NUMBER OF CYCLES (3 POUND)
101	M81381	270	48	20
106	M22759	323	47	12
111	BARCEL #1	319	38	12
116	BRAND REX #1	69	9	4
121	CHAMPLAIN #1	101	17	6
126	DUPONT #1	78	21	7
131	GORE #3	274	98	39
136	FILOTEX	1723	144	37
141	TENSOLITE #3	118	10	5
146	THERMATICS #3	694	85	22
151	NEMA #2	345	34	13
156	NEMA #3	90	25	7

TABLE 3.55 - ABRASION TEST RESULTS ON THERMALLY AGED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 150°C (302°F)

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES (1 POUND)	AVERAGE NUMBER OF CYCLES (2 POUND)	AVERAGE NUMBER OF CYCLES (3 POUND)
101	M81381	215	20	10
106	M22759	11	2	0
111	BARCEL #1	103	19	6
116	BRAND REX #1	18	3	2
121	CHAMPLAIN #1	26	5	3
126	DUPONT #1	12	2	1
131	GORE #3	111	10	0
136	FILOTEX	119	37	8
141	TENSOLITE #3	182	16	5
146	THERMATICS #3	216	83	21
151	NEMA #2	175	30	13
156	NEMA #3	34	5	2

TABLE 3.56 - ABRASION TEST RESULTS ON THERMALLY AGED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE AT 23°C (73°F)

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES (1 POUND)	AVERAGE NUMBER OF CYCLES (2 POUND)	AVERAGE NUMBER OF CYCLES (3 POUND)
102	M81381	108	33	8
107	M22759	138	21	6
112	BARCEL #1	98	16	6
117	BRAND REX #1	25	6	3
122	CHAMPLAIN #1	67	12	4
127	DUPONT #1	27	6	2
132	GORE #3	89	33	11
137	FILOTEX	460	60	33
142	TENSOLITE #3	43	7	3
147	THERMATICS #3	257	23	11
152	NEMA #2	144	23	11
157	NEMA #3	34	9	5

TABLE 3.57 - ABRASION TEST RESULTS ON THERMALLY AGED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE AT 150°C (302°F)

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES (1 POUND)	AVERAGE NUMBER OF CYCLES (2 POUND)	AVERAGE NUMBER OF CYCLES (3 POUND)
102	M81381	42	7	3
107	M22759	3	0	0
112	BARCEL #1	43	7	3
117	BRAND REX #1	20	3	1
122	CHAMPLAIN #1	20	3	2
127	DUPONT #1	4	1	0
132	GORE #3	20	0	0
137	FILOTEX	62	16	3
142	TENSOLITE #3	58	13	5
147	THERMATICS #3	77	25	6
152	NEMA #2	46	17	6
157	NEMA #3	1	1	1

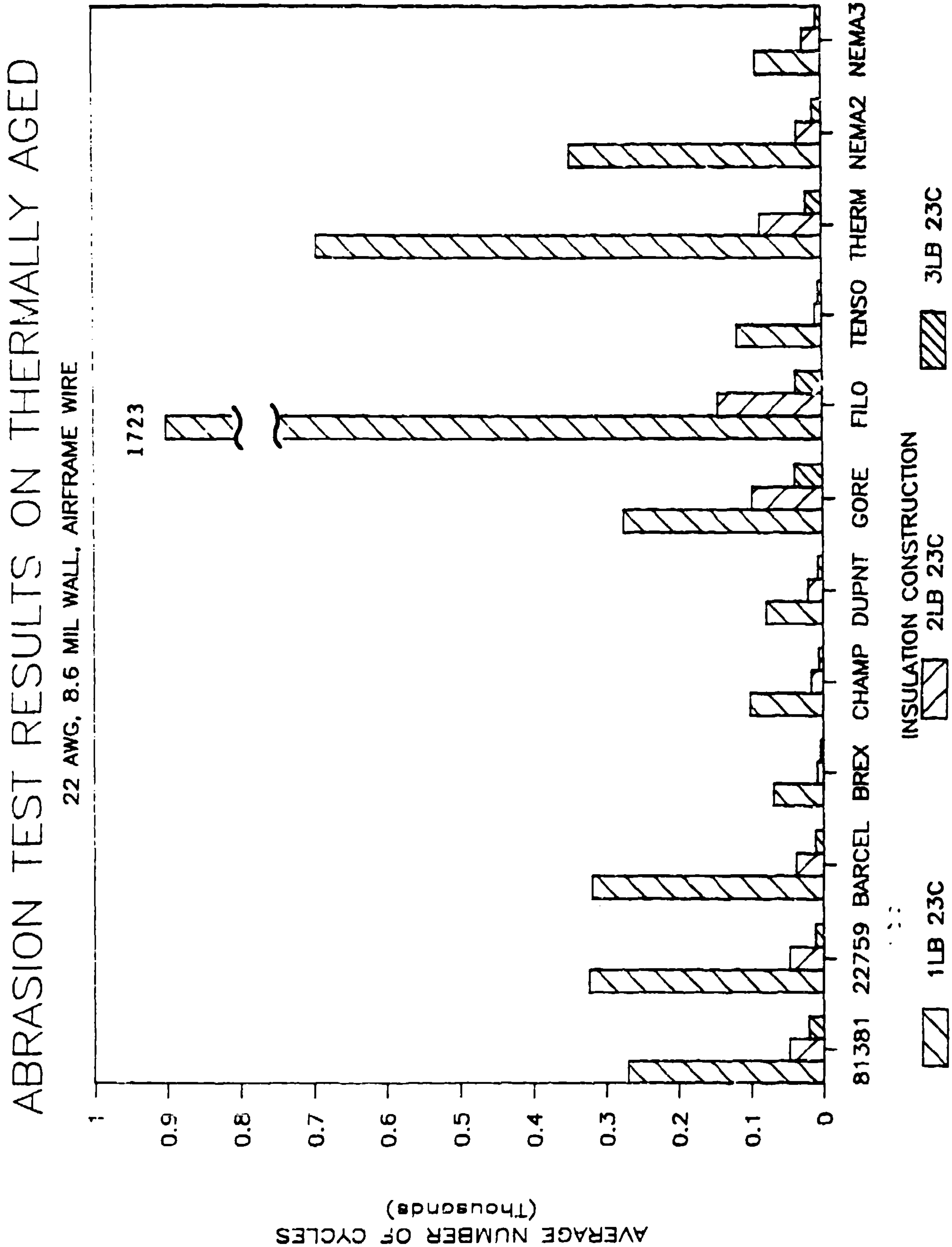


FIGURE 3.14 - ABRASION TEST RESULTS ON THERMALLY AGED, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 23°C

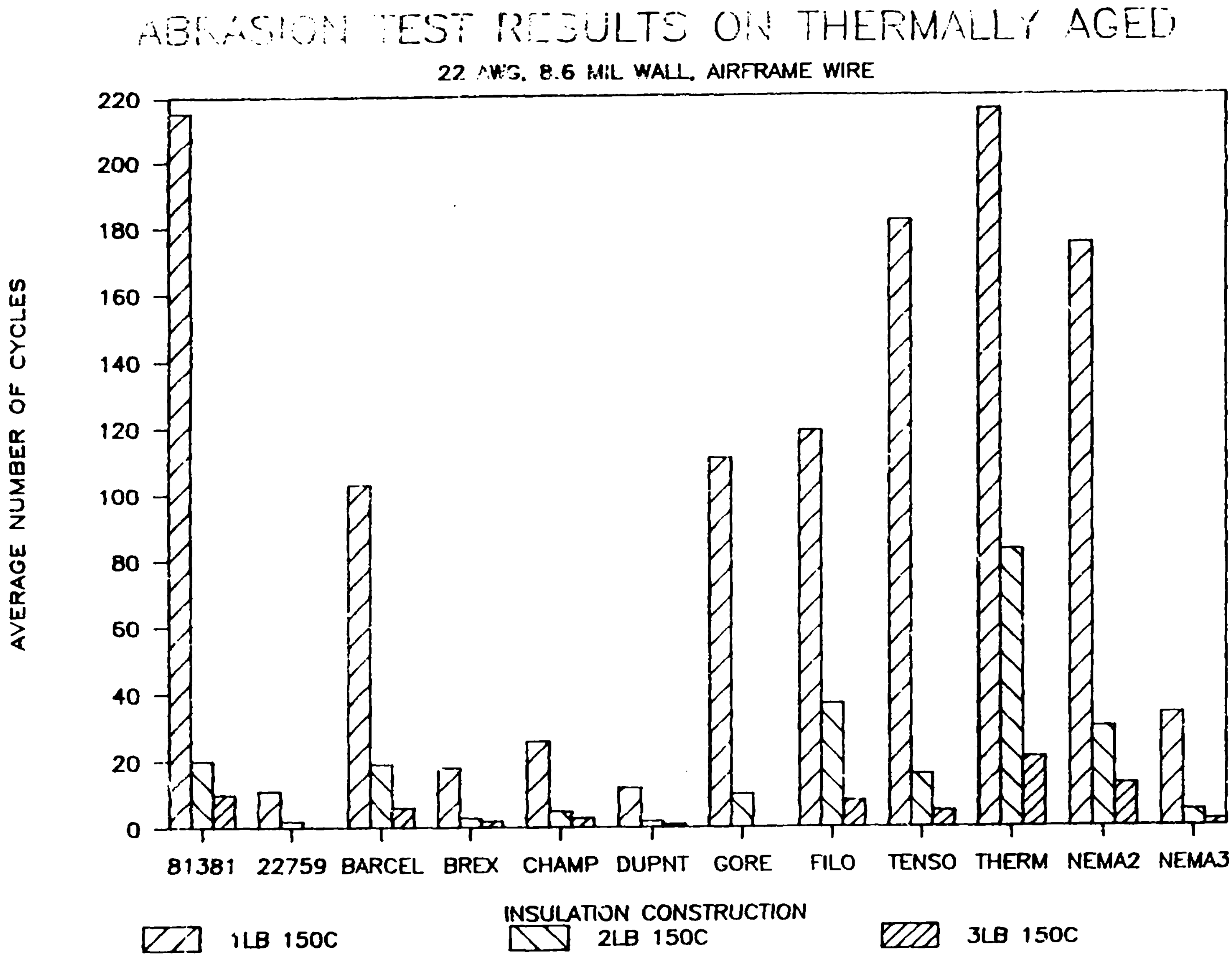


FIGURE 3.15 - ABRASION TEST RESULTS ON THERMALLY AGED, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 150°C

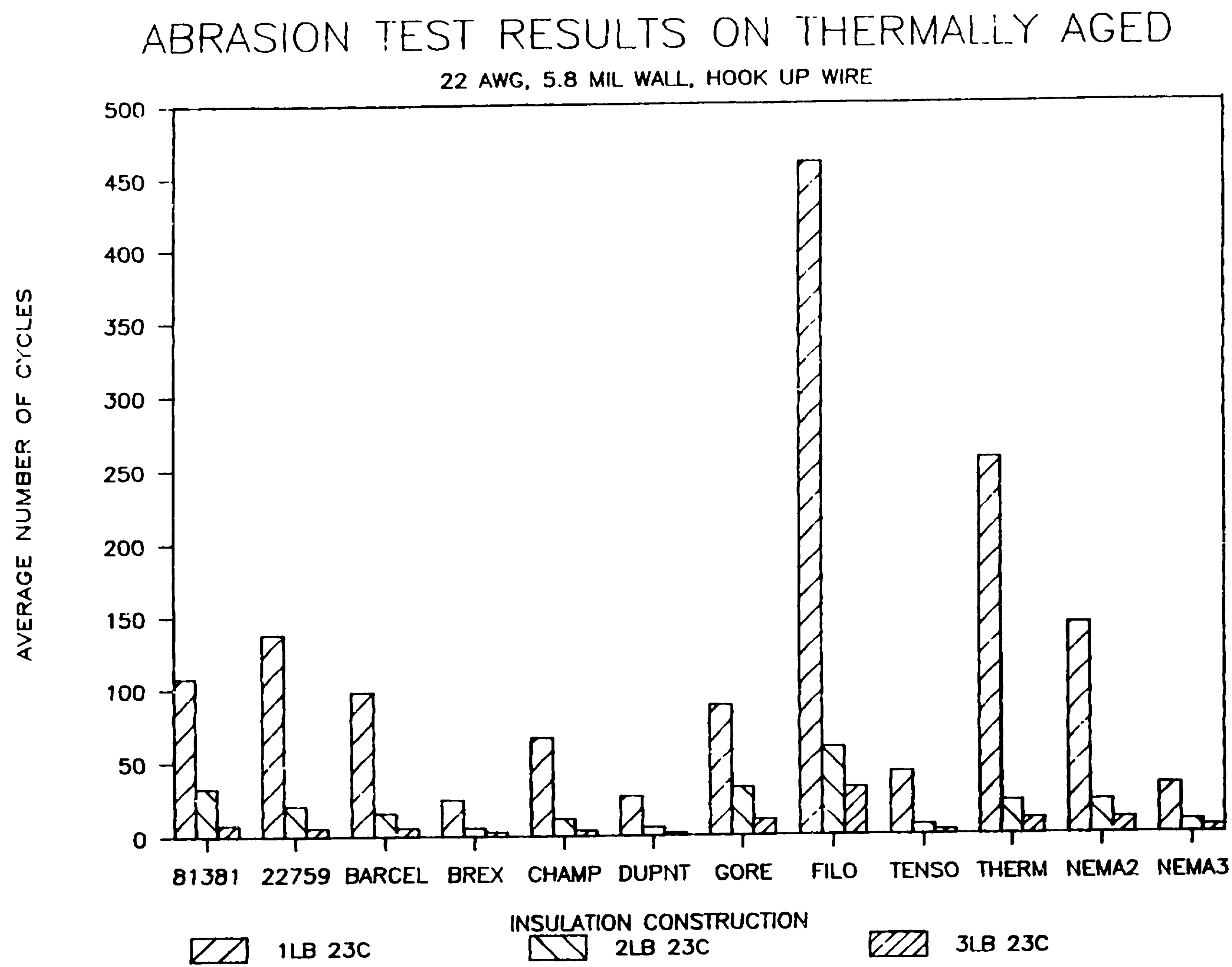


FIGURE 3.16 - ABRASION TEST RESULTS ON THERMALLY AGED, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 23°C

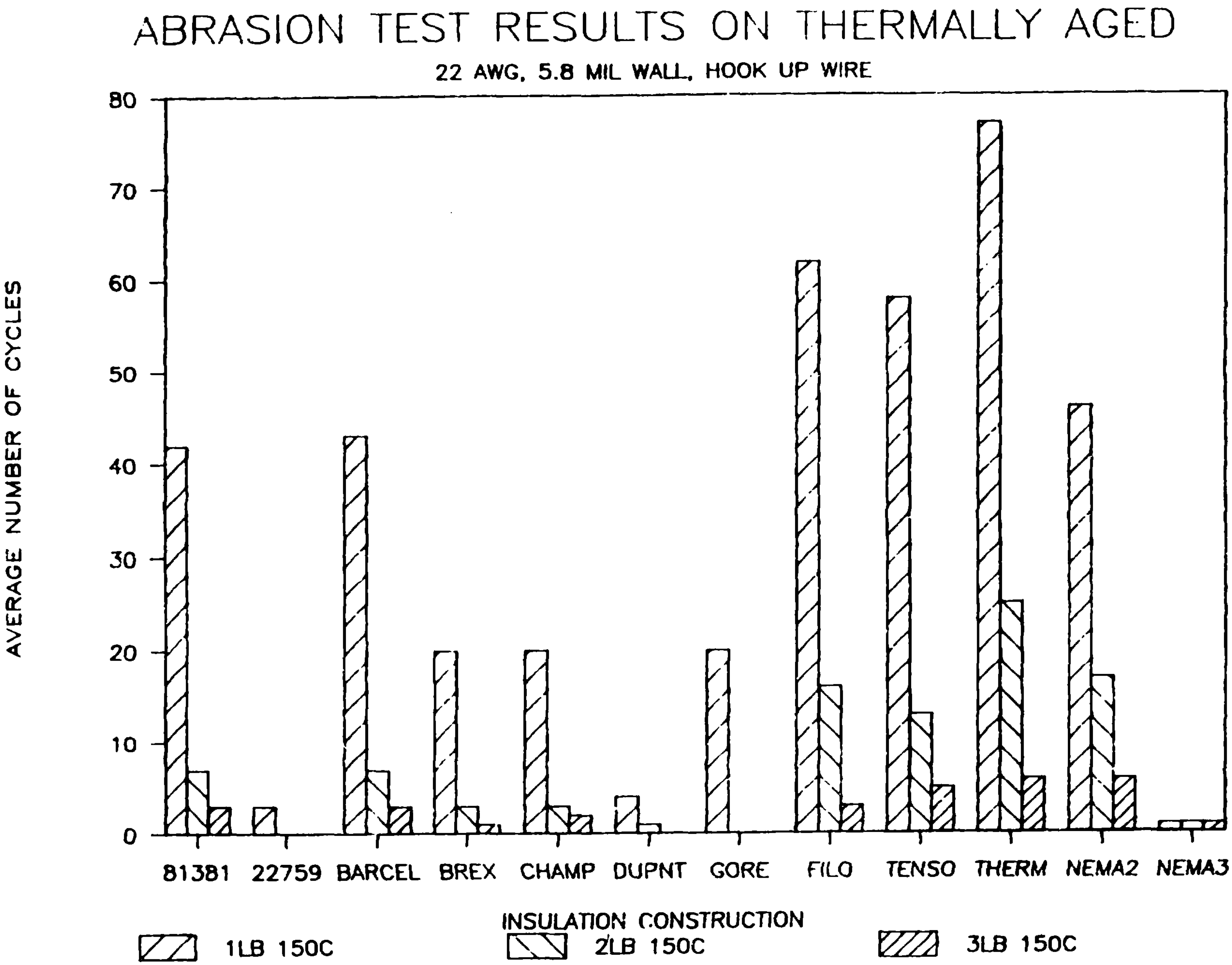


FIGURE 3.17 - ABRASION TEST RESULTS ON THERMALLY AGED, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 150°C

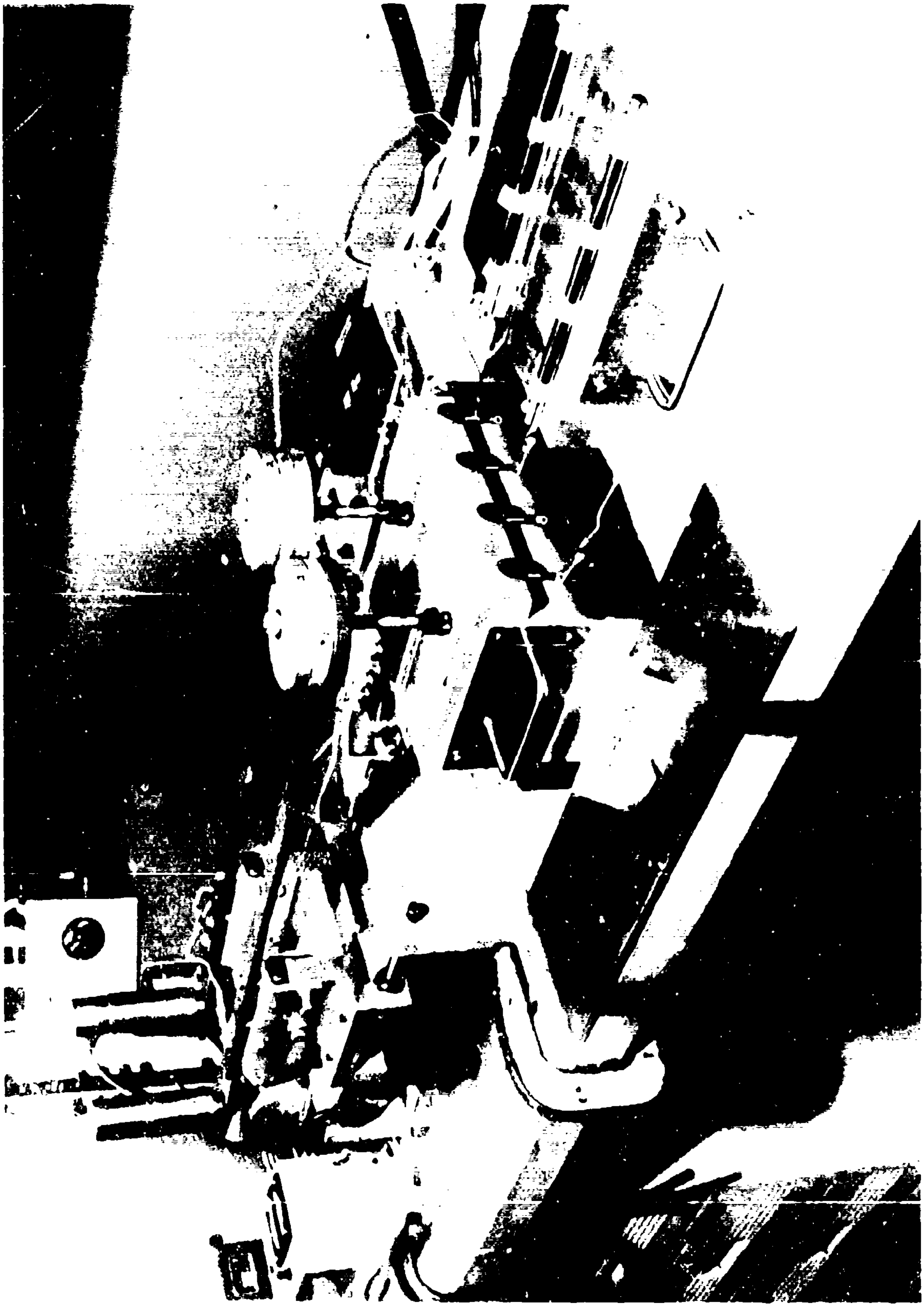


FIGURE 3.18 - ABRASION TEST SETUP AT 23°C (AMBIENT)

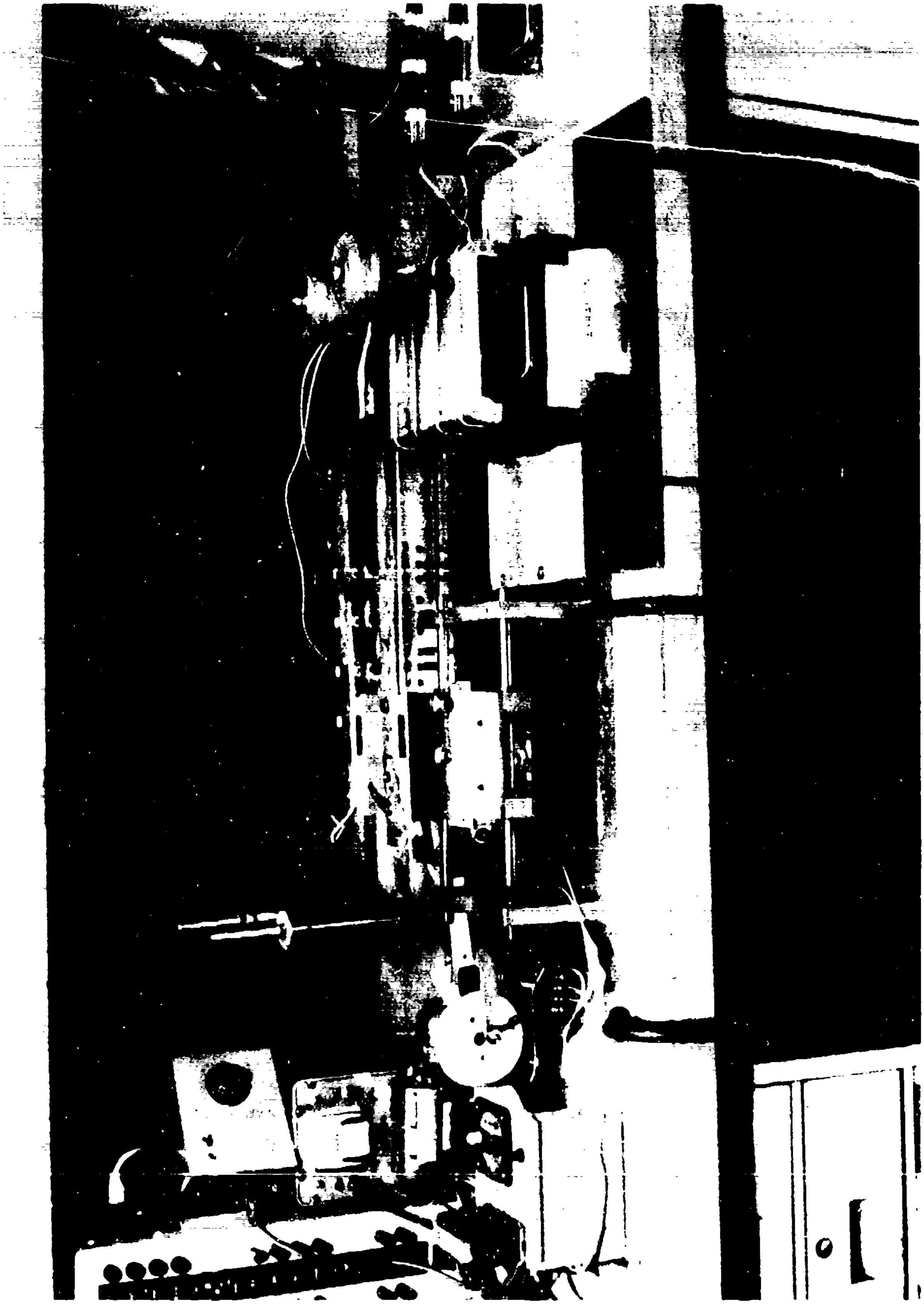


FIGURE 3.19 - ABRASION TEST SETUP AT 23°C (AMBIENT)

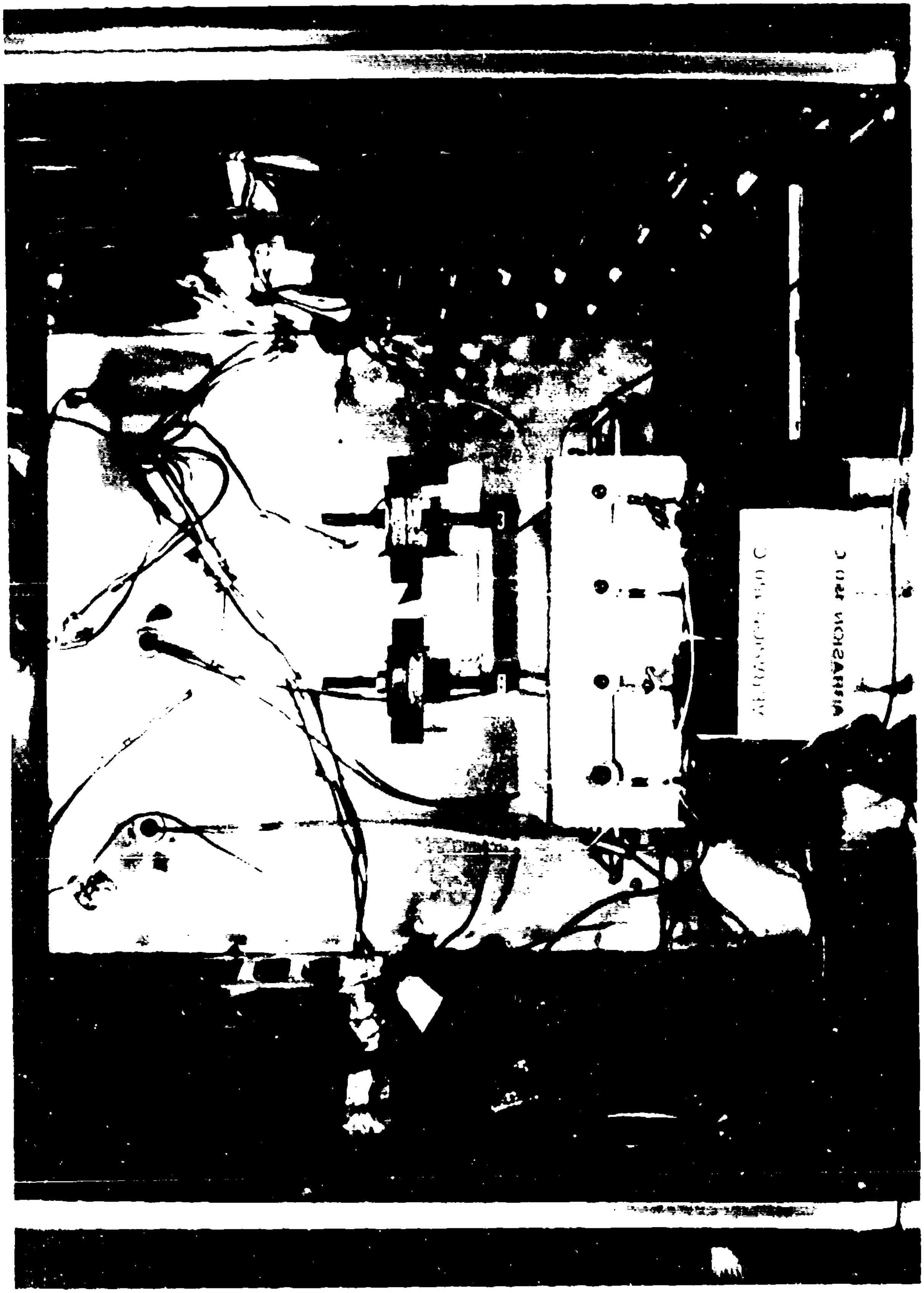


FIGURE 3.20 - ABRASION TEST SETUP AT 150°C

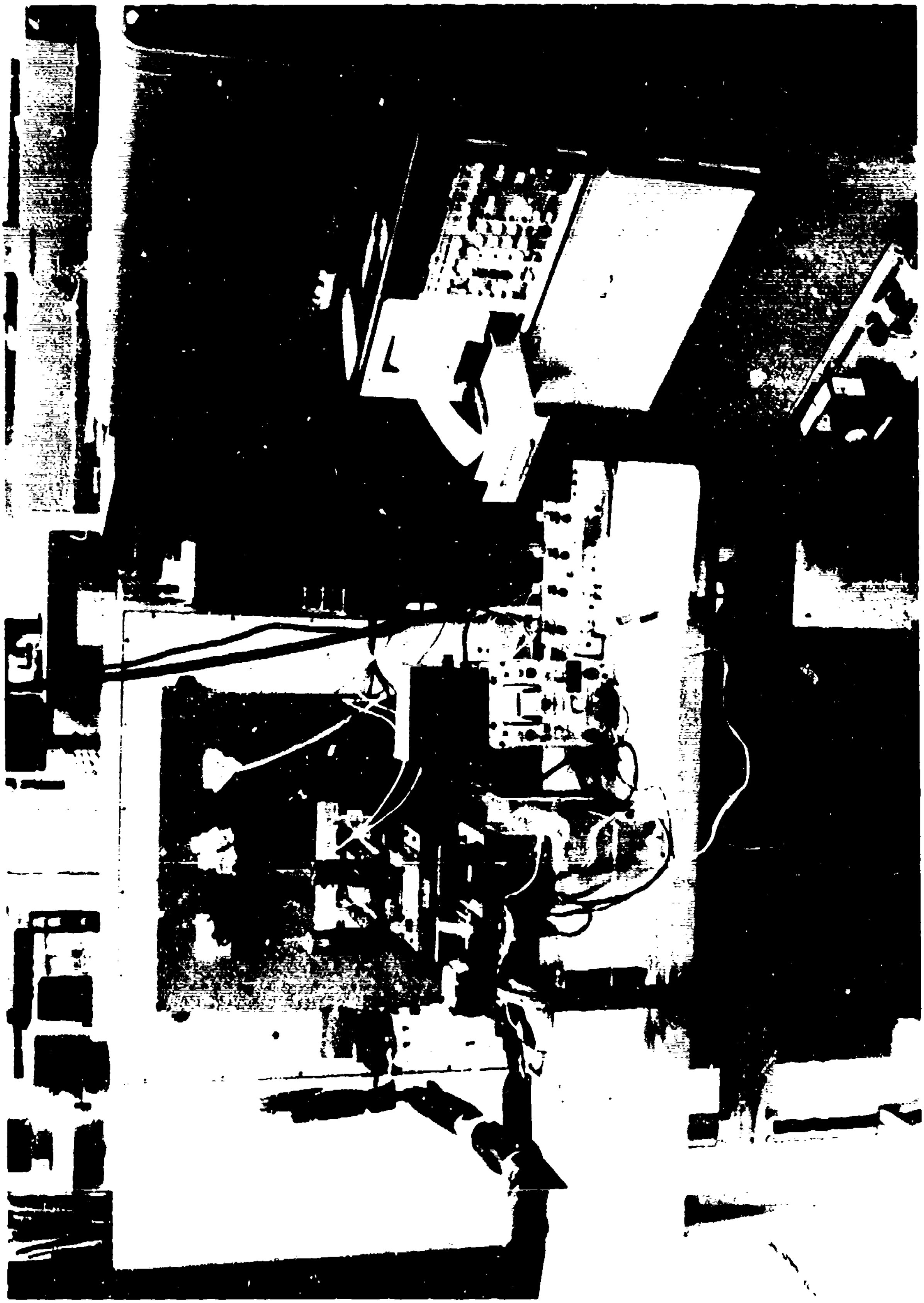


FIGURE 3.[illegible]1 - ABRASION TEST SETUP AT 150°C

3.7.2 DYNAMIC CUT THROUGH.

3.7.2.1 Scope: The Dynamic Cut Through test was used to evaluate the resistance of a wire insulation, thermally aged at 200°C (392°F) for 1000 hours, to the penetration of a cutting surface.

3.7.2.2 Reference Procedure: The Dynamic Cut Through Test was performed according to Method 703 of SAE AS4373 at 23°C (73°F), 70°C (158°F), 150°C (302°F), and 200°C (392°F) on thermally aged specimens.

3.7.2.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Eight specimens, thermally aged at 200°C (392°F) for 1000 hours, were constructed for each test temperature, for a total of 32 specimens per sample. The specimens were prepared by being cut into lengths of five inches with a quarter inch of insulation removed from one end.

Eight specimens were mounted one inch apart on a 4 x 10 x 0.75 inch flat steel plate with two specimens each at 0°, 90°, 180°, and 270° from the natural curvature (reel set) of the wire. The specimens were secured to the plate using high temperature aluminum tape.

3.7.2.4 Test Equipment: A Satec 60,000 Pound Load Frame (MD 078[illegible]) was used with a Revere 500 Pound Load Cell (MD [illegible]) to supply the force upon the specimen. A 12 volt dc detection circuit was usod to instruct the operator to stop the machine after continuity was achieved between the cutting tool and the specimen's conductor. The load cell was monitored by a Hewlett-Packard 7047A X-Y Recorder (MD 79030).

The cutting tool was a 1.5 inch, 20 mil diameter tungsten carbide rod, silver soldered to a holding fixture. The rod had a 4 to 6 micro-inch finish.

An Omega HH-51 Digital Thermometer (MD 202322) with a K type thermocouple was used to measure the elevated temperatures.

The Dynamic Cut Through test was conducted in Department 256, Mechanical Properties Laboratory.

Photographs of the test setup and equipment are provided in Figures 3.28 through 3.29.

3.7.2.5 Test Procedure: The specimens were placed under the cutting tool and a 12 volt dc detection circuit was connected to the test specimen. The detection circuit was used to detect continuity between the conductor and the tool. The tool was pressed against one wire at a rate of 0.2 inches per minute until electrical continuity with the conductor was detected. The amount of force applied during the process of penetrating the insulation

was recorded on an X-Y recorder. The mounting plate was then moved to place a new specimen under the cutting tool and the test was repeated until all eight specimens of each wire sample were tested.

The test was repeated at elevated temperatures of 70°C (156°F), 150°C (302°F), and 200°C (392°F). For the elevated temperatures, specimens mounted to the plates were placed in the oven with thermocouples attached to the plates. The test was conducted no earlier than one hour after the plates stabilized at that particular temperature. After opening the chamber door to reposition the test plate, there was a five minute wait to re-stabilize the chamber temperature before the test was conducted on the new specimen.

The eight force values were averaged to acquire an average dynamic cut through value for that particular wire sample and temperature.

3.7.2.6 Test Results: The average force values to penetrate the insulation at 23°C (70°F), 70°C (156°F), 150°C (302°F), and 200°C (392°F) are presented in Tables 3.58 through 3.60 with graphical representation of data provided in Figures 3.22 through 3.27.

TABLE 3.58 - DYNAMIC CUT THROUGH TEST RESULTS ON THERMALLY AGED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE AT 23 °C (POUNDS)	AVERAGE FORCE AT 70 °C (POUNDS)	AVERAGE FORCE AT 150 °C (POUNDS)	AVERAGE FORCE AT 200 °C (POUNDS)
101	M81381	82.0	73.0	57.2	50.7
106	M22759	60.8	32.7	7.0	3.2
111	BARCEL #1	52.3	46.4	29.4	22.1
116	BRAND REX #1	51.7	46.6	31.2	24.8
121	CHAMPLAIN #1	57.0	51.8	40.7	37.7
126	DUPONT #1	42.5	31.6	17.0	11.0
131	GORE #3	34.3	32.8	18.2	15.9
136	FILOTEX	38.0	29.3	27.0	20.8
141	TENSOLITE #3	50.8	47.3	40.9	36.1
146	THERMATICS #3	39.0	47.6	39.9	38.0
151	NEMA #2	45.3	47.0	42.1	32.7
156	NEMA #3	60.9	53.0	42.6	35.1

TABLE 3.59 - DYNAMIC CUT THROUGH TEST RESULTS ON THERMALLY AGED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE AT 23 °C (POUNDS)	AVERAGE FORCE AT 70 °C (POUNDS)	AVERAGE FORCE AT 150 °C (POUNDS)	AVERAGE FORCE AT 200 °C (POUNDS)
102	M81381	67.6	59.2	47.1	40.5
107	M22759	32.7	16.9	4.1	2.6
112	BARCEL #1	39.9	36.5	24.9	17.6
117	BRAND REX #1	53.2	46.6	36.4	32.7
122	CHAMPLAIN #1	46.9	42.2	41.5	36.5
127	DUPONT #1	33.0	22.1	10.9	7.9
132	GORE #3	27.6	28.1	24.7	29.3
137	FILOTEX	32.4	27.5	25.5	18.2
142	TENSOLITE #3	51.3	46.2	39.9	34.7
147	THERMATICS #3	34.3	41.8	33.5	31.3
152	NEMA #2	48.5	47.7	36.9	30.8
157	NEMA #3	52.1	47.0	40.5	33.1

TABLE 3.60 - DYNAMIC CUT THROUGH TEST RESULTS ON THERMALLY AGED, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE AT 23 °C (POUNDS)	AVERAGE FORCE AT 70 °C (POUNDS)	AVERAGE FORCE AT 150 °C (POUNDS)	AVERAGE FORCE AT 200 °C (POUNDS)
103	M81381	49.6	33.5	21.3	16.8
108	M22759	20.4	10.4	3.8	2.2
113	BARCEL #1	14.8	10.9	8.1	6.7
118	BRAND REX #1	33.9	24.1	10.8	9.8
123	CHAMPLAIN #1	16.6	12.2	8.3	6.4
128	DUPONT #1	17.4	13.0	7.8	6.1
133	GORE #3	8.7	5.1	3.6	2.2
138	FILOTEX	15.7	13.9	11.5	8.0
143	TENSOLITE #3	15.8	16.4	12.0	8.2
148	THERMATICS #3	18.0	24.9	9.7	6.9
153	NEMA #2	16.0	14.8	12.0	9.1
158	NEMA #3	21.5	15.5	7.6	5.2

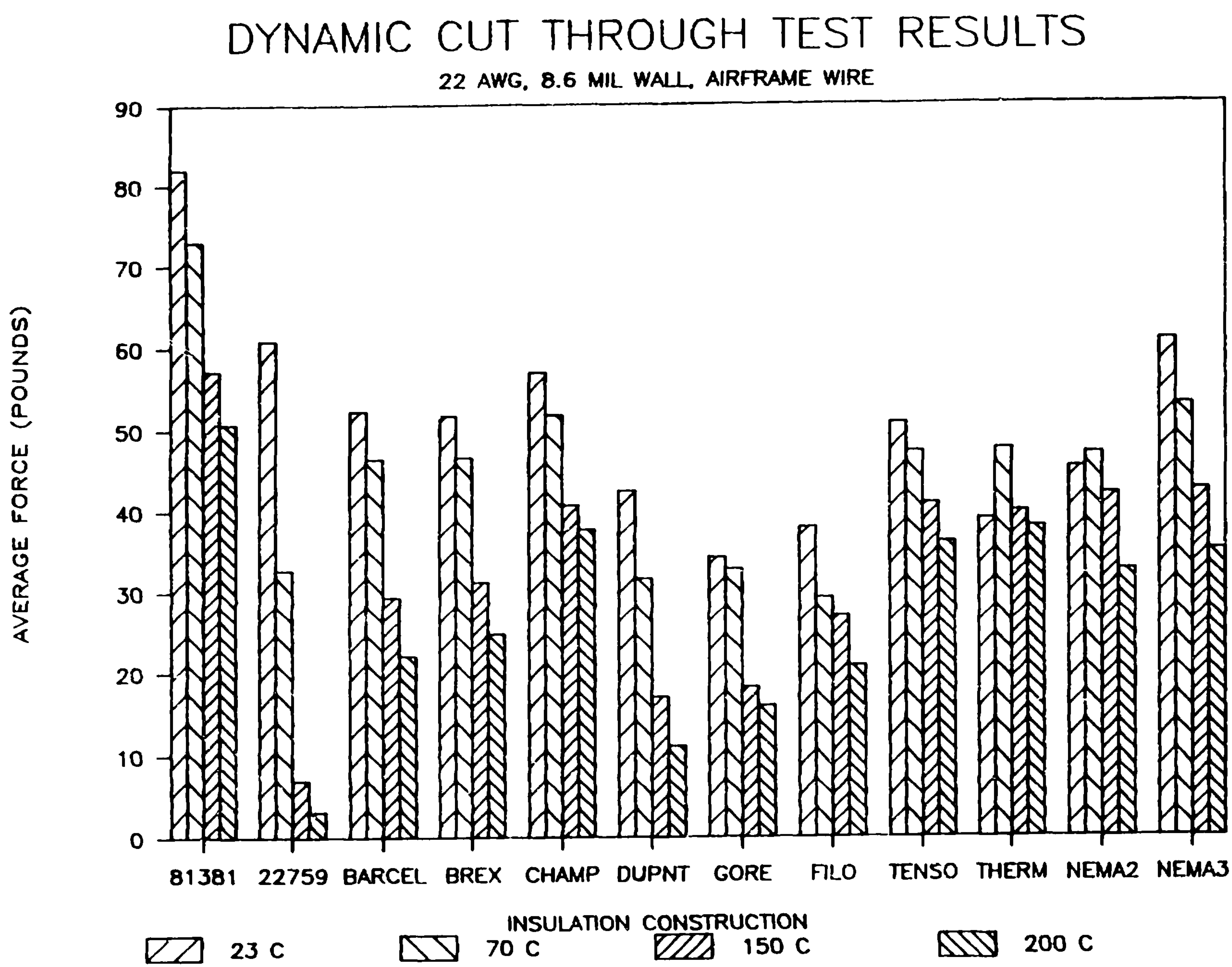


FIGURE 3.22 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

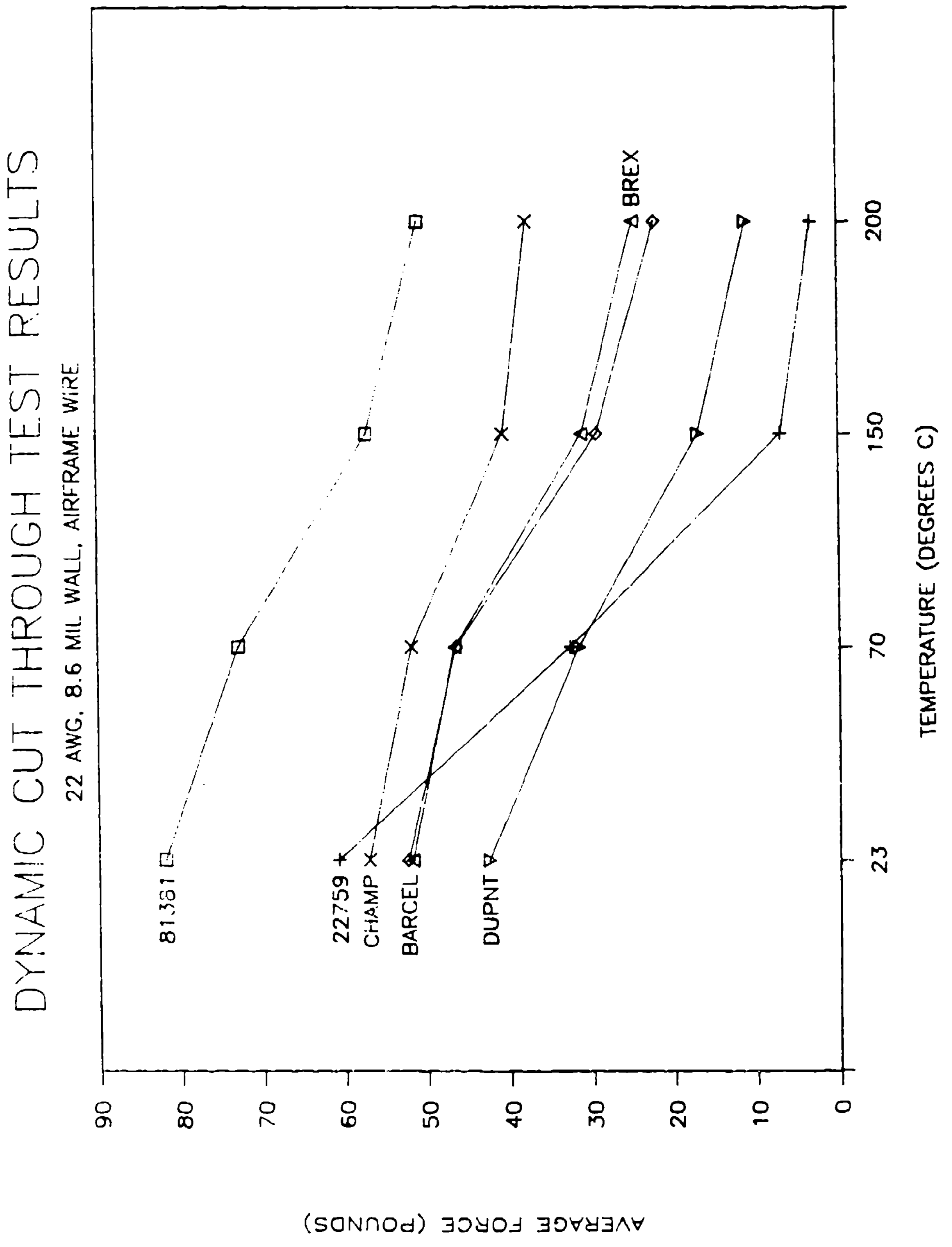


FIGURE 3.23 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

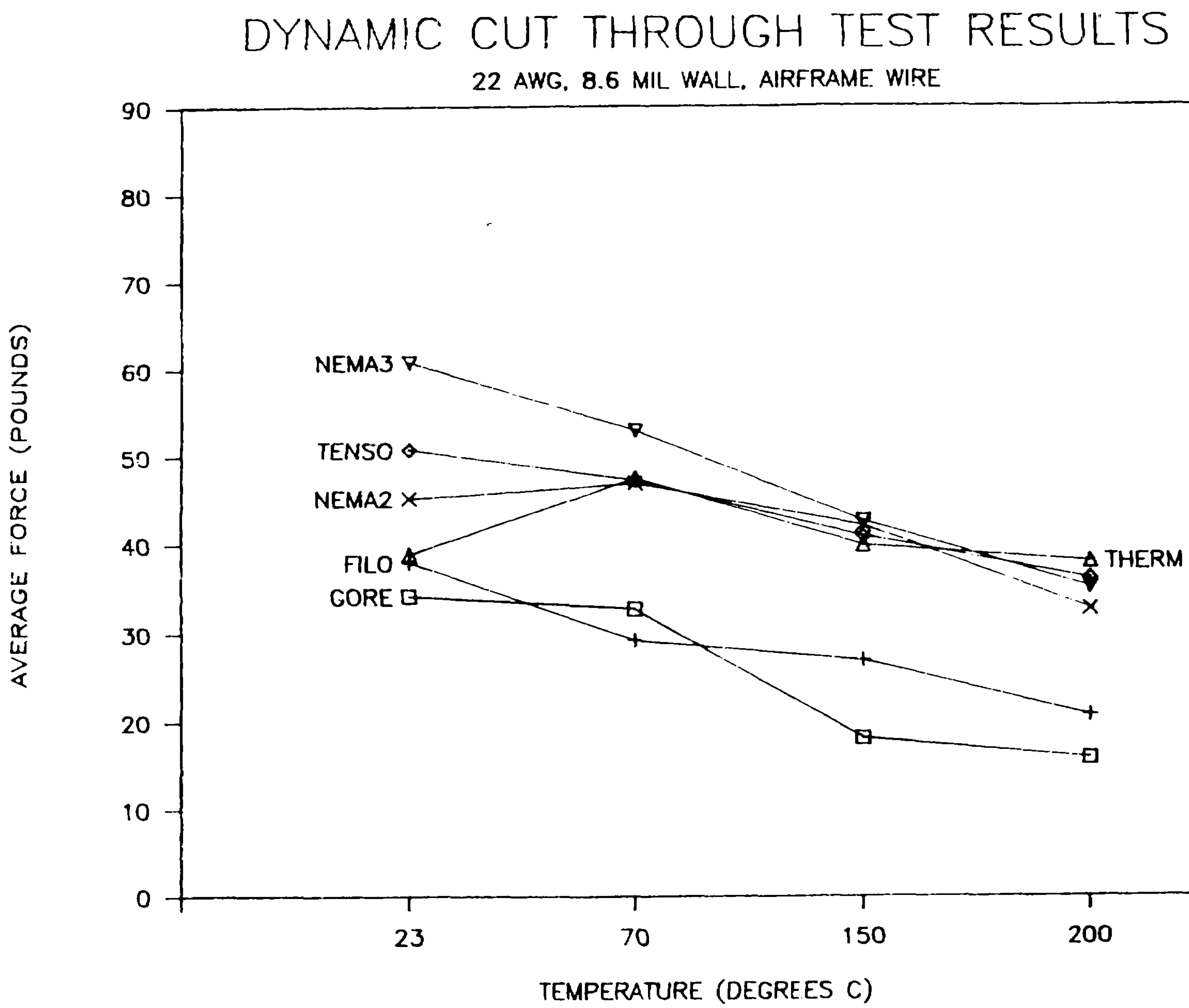


FIGURE 3.23 - DYNAMIC CUT THROUGH TEST RESULTS,
22AWG, 8.6 MIL WALL, AIRFRAME WIRE (Cont.)

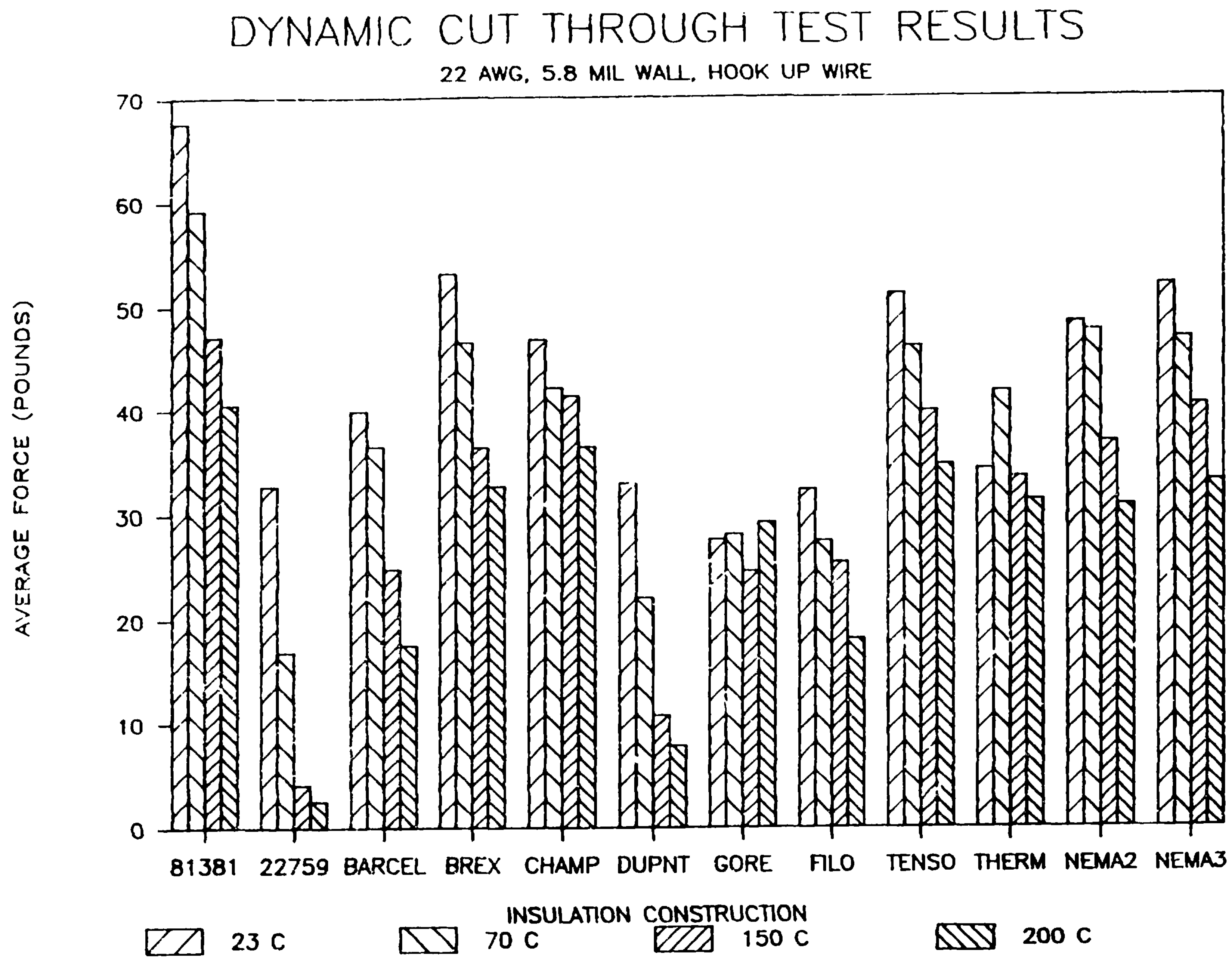


FIGURE 3.24 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

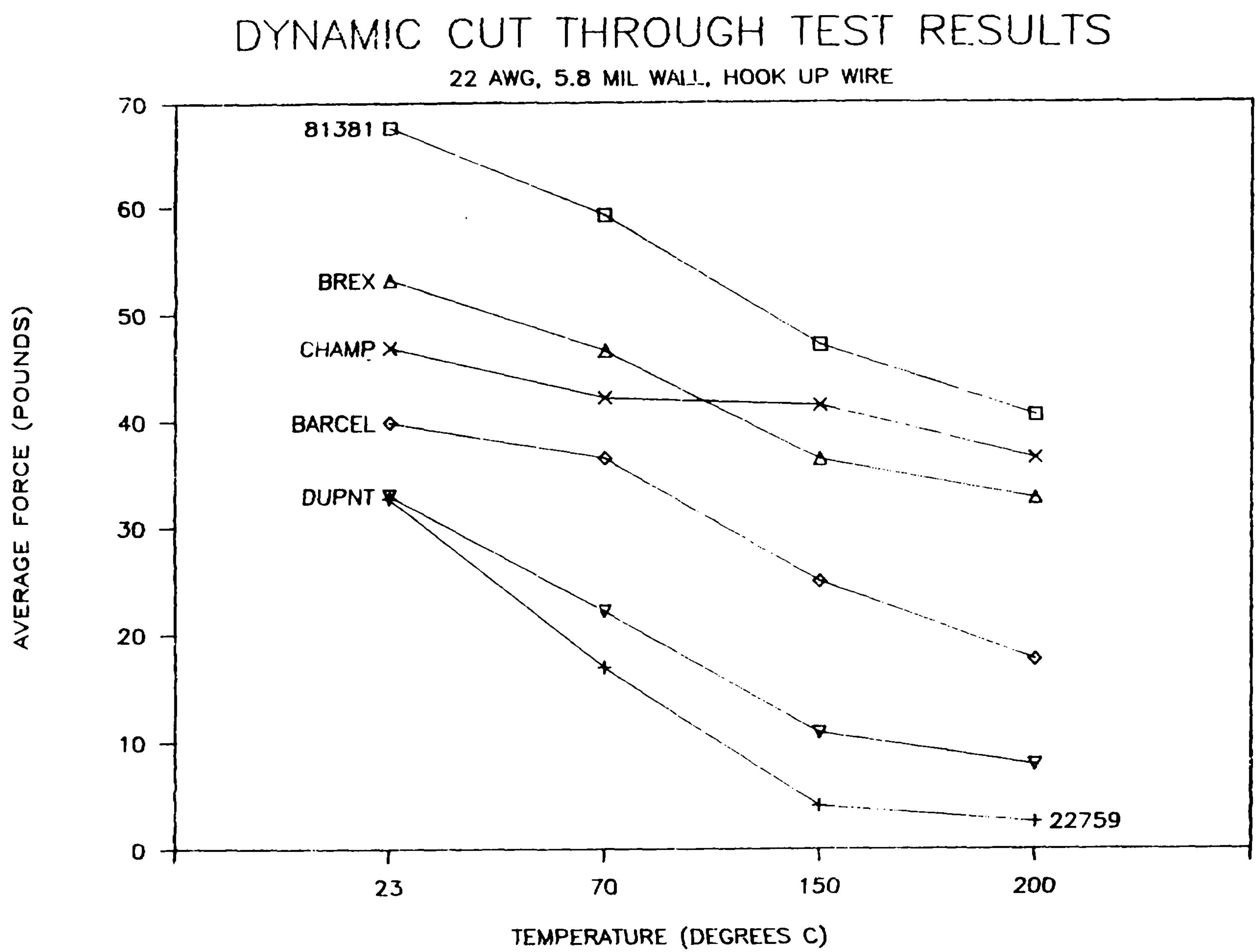


FIGURE 3.25 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

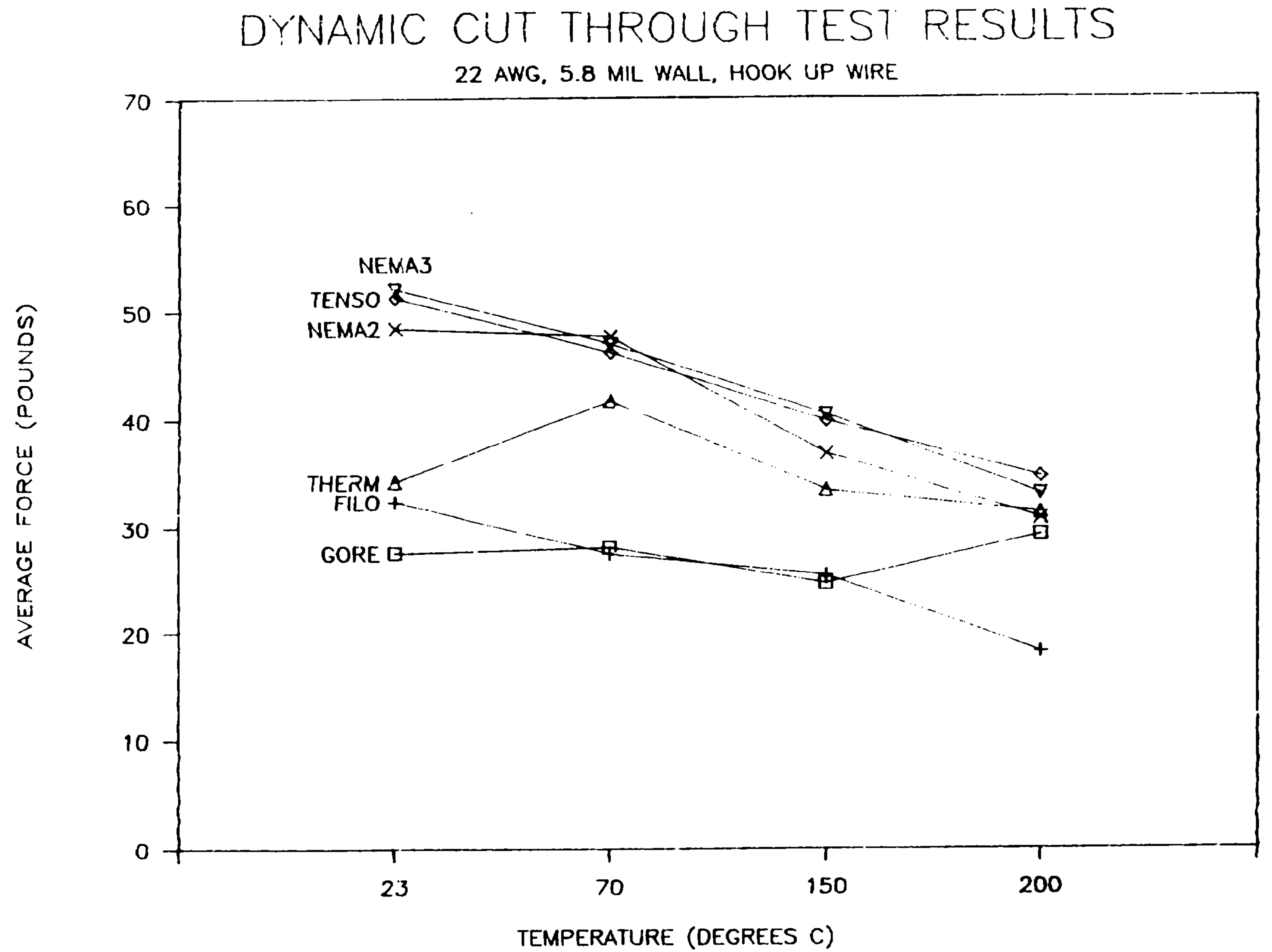


FIGURE 3.25 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE (Cont.)

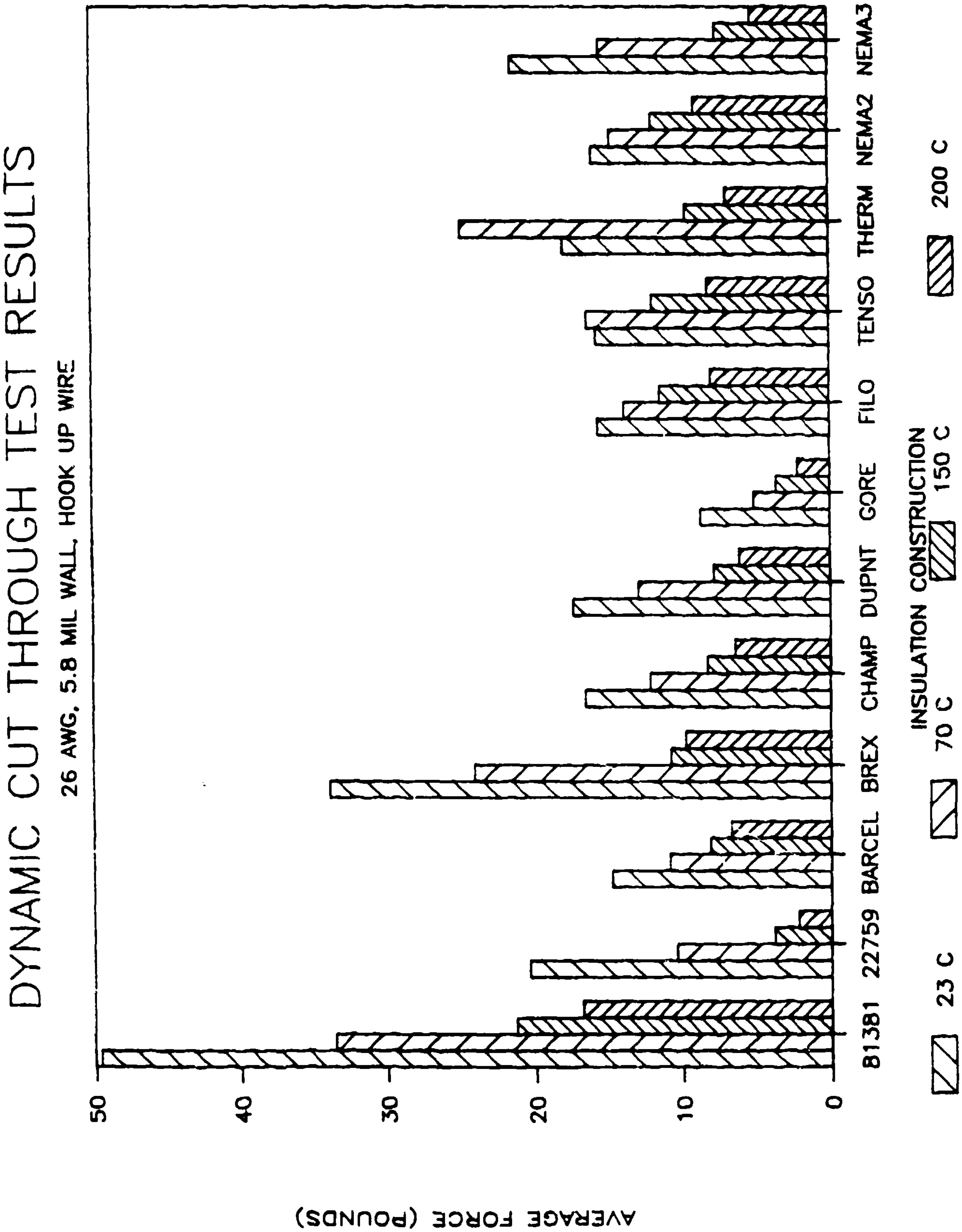


FIGURE 3.26 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

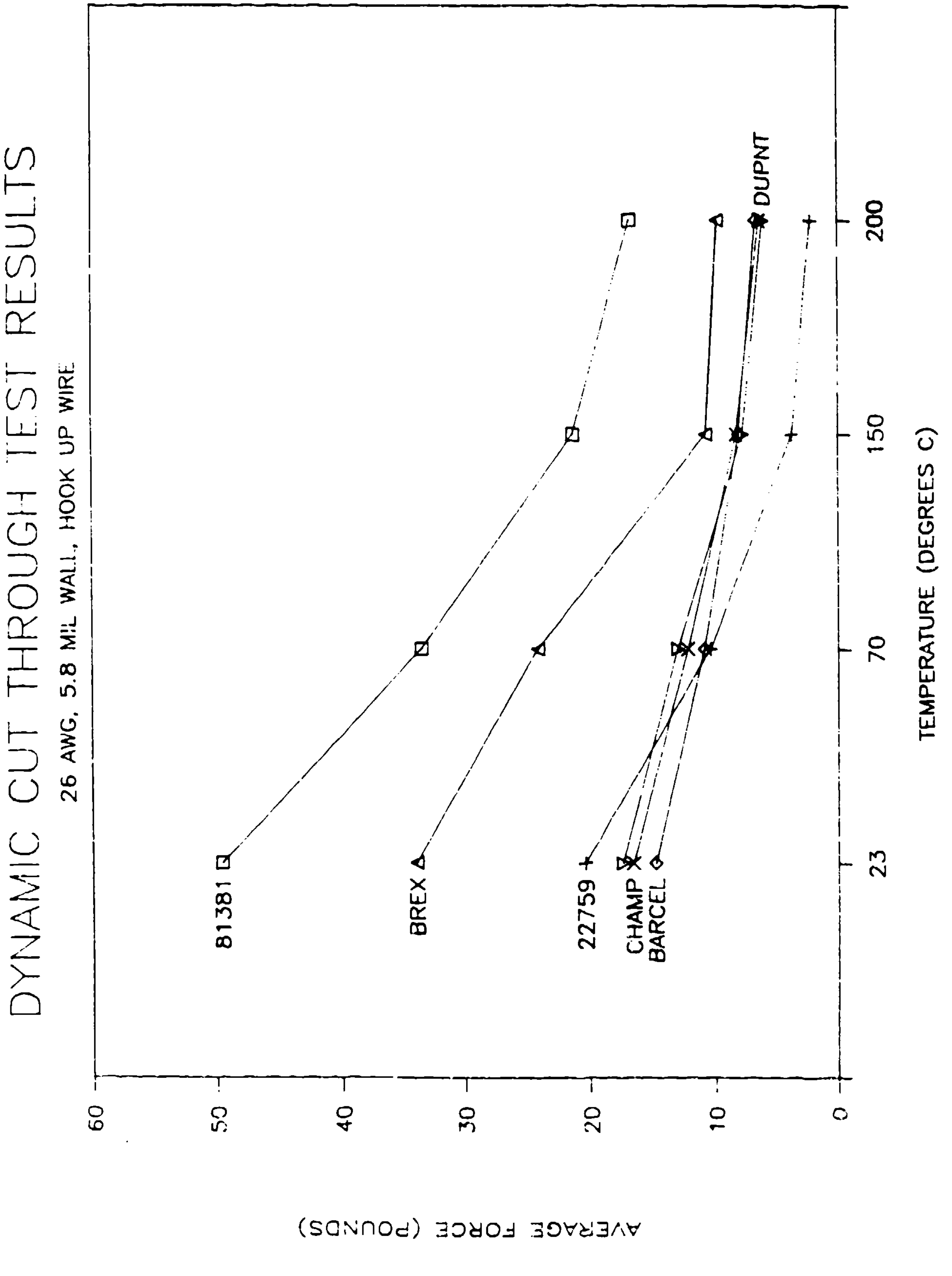


FIGURE 3.27 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

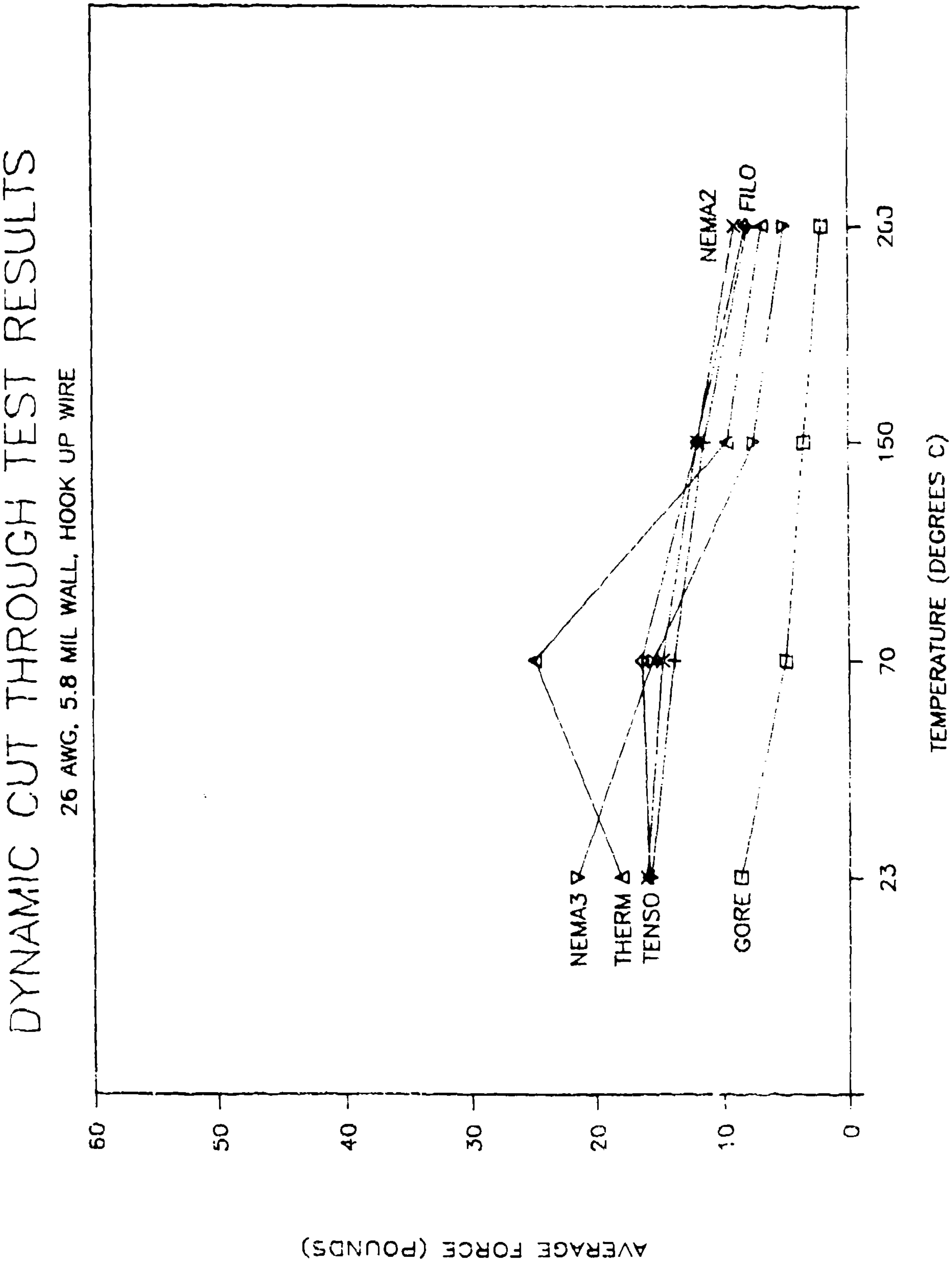


FIGURE 3.27 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE (Cont.)

FIGURE 3.28 - DYNAMIC CUT THROUGH TEST SETUP

FIGURE [illegible] - DYNAMIC CUT THROUGH TEST SETUP

3.7.3 FLEX LIFE.

3.7.3.1 Scope: The Flex Life test was used to determine the mechanical flex strength of the conductor and insulation that has been thermally aged at 200°C (392°F) for 1000 hours.

3.7.3.2 Reference Procedure: The Flex Life test was conducted according to MDC B0482 (Method 704 of SAE AS4373 was not available) with the following modifications. The weight used to apply tension shall be 20% of the conductors break strength. A failure was defined as a 115% change in the conductor's resistance or visual observation of the conductor at the flex point.

3.7.3.3 Specimens: Specimens of 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire were constructed for the test. Six specimens were cut to a length of 18 inches for each sample. A half inch of insulation was removed and a spade lug was crimped on the conductor at one end to attach the specimen to the flexing arm. The other end of the specimen had approximately two inches of insulation removed with no damage to the conductor strands. A nine inch instrumentation lead was crimped on the conductor using a crimp splice (ST5M1345-002)

approximately 1.5 inches from the end of the specimen. This lead monitored the conductor's resistance. A twelve inch instrumentation lead and the conductor end were crimped together in a #10 ring terminal to support a weight and hold the specimen taut during flexing.

3.7.3.4 **Test Equipment:** A Daytronics Data Acquisition System (MD 122188) with appropriate input/output cards was used to monitor the resistance of the specimens and record the number of cycles for a 115% increase in resistance. The Daytronics System monitored the resistance change of the specimen with a constant current of 0.5 amps passing through the specimen.

Mandrels were required that were approximately six times the outer diameter of the specimen being flexed. The mandrel diameters used were 0.28 inch for the 22 gauge, 8.6 mil wall wires; 0.25 inch for the 22 gauge, 5.8 mil wall wires; and 0.19 inch for the 26 gauge, 5.8 mil wall, wires. The mandrels were covered with one layer of 5 mil Teflon tape to reduce friction. This tape was replaced for each new set of test specimens.

A four pound weight representing 20% of conductor break strength was applied to the 22 and 26 gauge specimens to apply tension during flexing.

Photographs of the test setup and equipment are provided in Figures 3.31 through 3.32.

3.7.3.5 Test Procedure: Three wire specimens were clamped to a pivoting arm six inches above a pair of the appropriate sized mandrels. Spacers one and two mils thick were placed, one on each end, in between the mandrel openings. The mandrels were adjusted until snug against both spacers and the spacers were removed. The mandrels were adjusted so that a two mil spacer would pass between the mandrel and the specimen but a three mil spacer would not. Guides were placed by the weights to minimize weight swing during the test.

The specimens were flexed 90° from vertical in one direction, back to vertical, 90° from vertical in the other direction, and back to vertical for one cycle. The flex arm was cycled at a rate of 30 cycles per minute until a 115% resistance increase failure occurred, a crack in the insulation occurred that made the conductor visible or the wire broke at the flex point.

The number of cycles to failure was recorded as well as the type of failure encountered.

3.7.3.6 Test Results: The average number of cycles to failure and the type of failures encountered are presented in Tables 3.61 through 3.63 with graphical representation of the data presented in Figure 3.30.

TABLE 3.61 - FLEX LIFE TEST RESULTS ON THERMALLY AGED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	QUANTITY PER TYPE OF FAILURE: 115% INCREASE IN RESIST.	QUANTITY PER TYPE OF FAILURE: CRACK IN INSUL. OBSERVED CONDUCTOR	QUANTITY PER TYPE OF FAILURE: SPECIMEN BROKE AT FLEXING POINT
101	M81381	479	3	0	3
106	M22759	59	0	6	0
111	BARCEL #1	335	3	0	3
116	BRAND REX #1	94	3	0	3
121	CHAMPLAIN #1	143	1	0	5
126	DUPONT #1	1	0	6	0
131	GORE #3	494	6	0	0
136	FILOTEX	100	6	0	0
141	TENSOLITE #3	113	6	0	0
146	THERMATICS #3	213	4	0	2
151	NEMA #2	203	6	0	0
156	NEMA #3	210	1	0	5

TABLE 3.62 - FLEX LIFE TEST RESULTS ON THERMALLY AGED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	QUANTITY PER TYPE OF FAILURE: 115% INCREASE IN RESIST.	QUANTITY PER TYPE OF FAILURE: CRACK IN INSUL. OBSERVED CONDUCTOR	QUANTITY PER TYPE OF FAILURE: SPECIMEN BROKE AT FLEXING POINT
102	M81381	297	0	0	6
107	M22759	60	0	0	6
112	BARCEL #1	108	1	0	5
117	BRAND REX #1	51	0	0	6
122	CHAMPLAIN #1	128	4	0	2
127	DUPONT #1	1	0	6	0
132	GORE #3	302	6	0	0
137	FILOTEX	89	5	0	1
142	TENSOLITE #3	82	6	0	0
147	THERMATICS #3	96	3	0	3
152	NEMA #2	75	0	0	6
157	NEMA #3	116	1	0	5

TABLE 3.63 - FLEX LIFE TEST RESULTS ON THERMALLY AGED, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

			QUANTITY PER TYPE OF FAILURE		
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	115% INCREASE IN RESIST.	CRACK IN INSUL. OBSERVED CONDUCTOR	SPECIMEN BROKE AT FLEXING POINT
103	M81381	238	0	0	6
108	M22759	39	0	2	4
113	BARCEL #1	124	2	0	4
118	BRAND REX #1	229	2	0	4
123	CHAMPLAIN #1	238	2	0	4
128	DUPONT #1	1	0	6	0
133	GORE #3	96	6	0	0
138	FILOTEX	39	6	0	0
143	TENSOLITE #3	111	0	0	6
148	THERMATICS #3	145	6	0	0
153	NEMA #2	76	0	0	6
158	NEMA #3	347	1	0	5

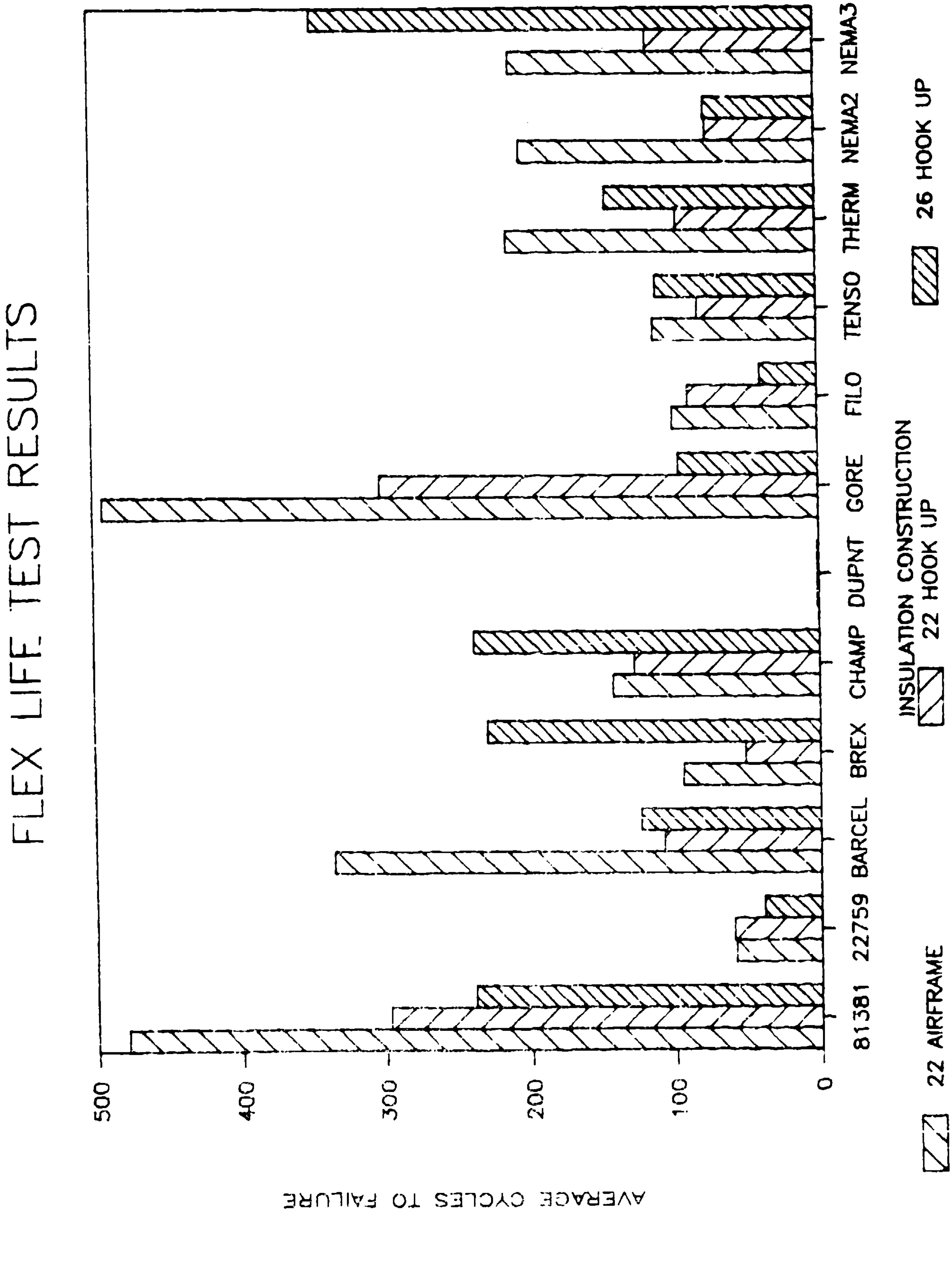


FIGURE 3.30 - FLEX LIFE TEST RESULTS

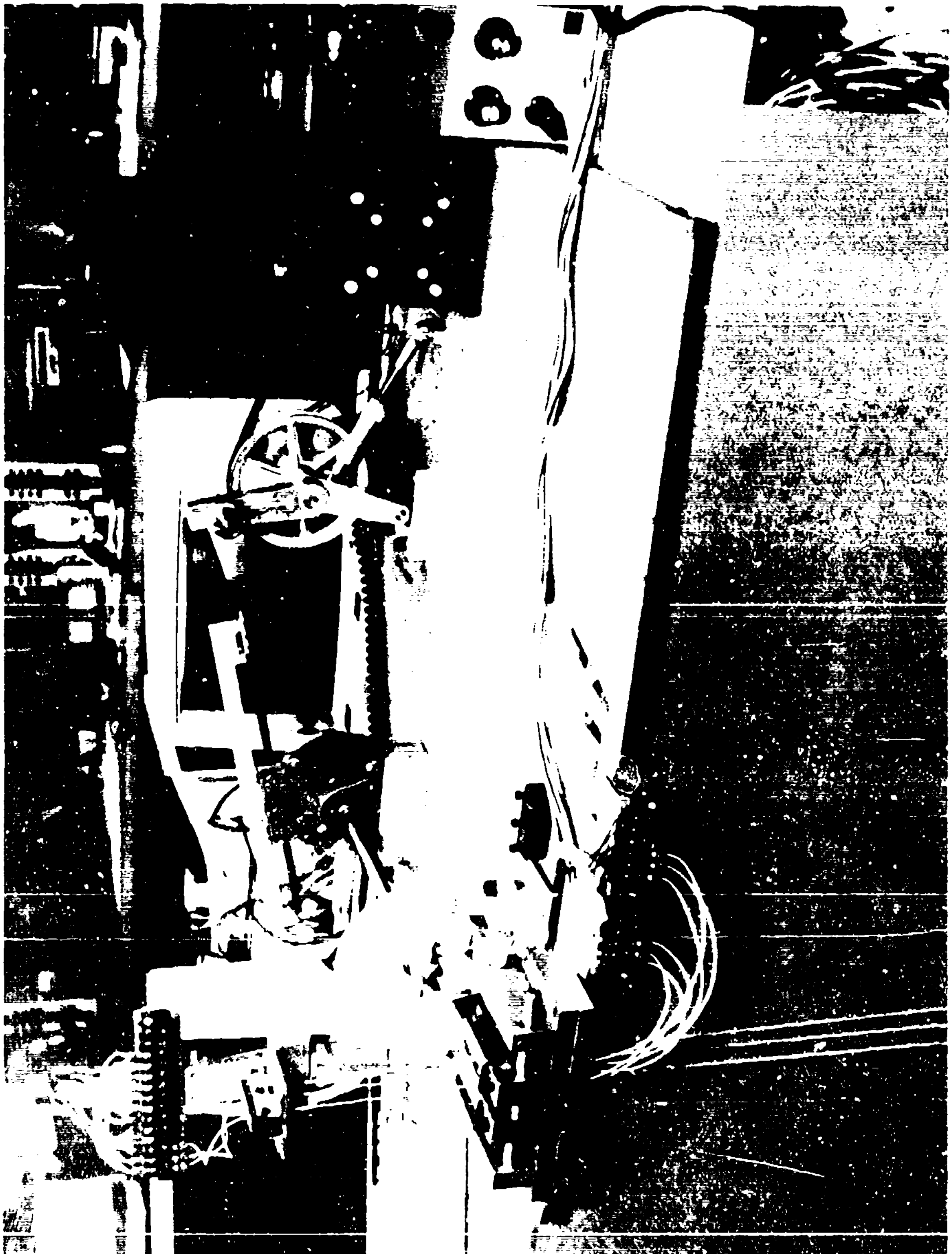


FIGURE [illegible].31 - FLEX LIFE TEST SETUP

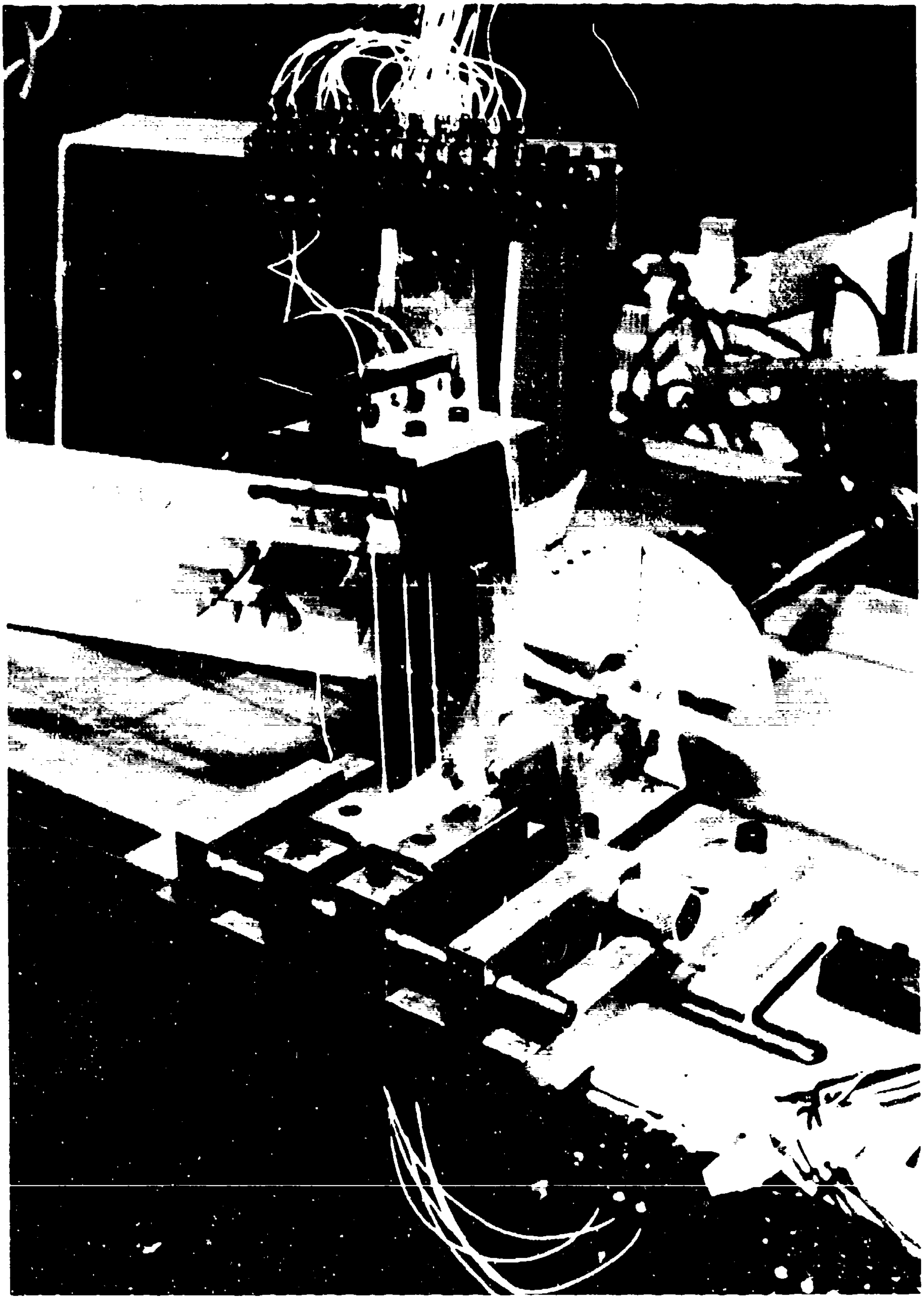


FIGURE 3.32 - FLEX LIFE TEST SETUP

3.7.4 NOTCH PROPAGATION.

3.7.4.1 Scope: The Notch Propagation Test was used to evaluate the ability of a wire insulation to withstand notching or nicking without propagating the damage down to the conductor. Prior to testing, the specimens were thermally aged for 1000 hours at 200°C (392°F).

3.7.4.2 Reference Procedure: The Notch Propagation Test was performed according to the procedure described in Method 707 of SAE AS4373 with the addition of a Voltage Withstand Test to confirm a failure. This test assumed that all thin wall wire had a wall thickness of 0.0058 inches and all medium wall wire had a wall thickness of 0.0086 inches. The test utilized tools with notch depths of 50% and 66.67% of the assumed wall thickness.

3.7.4.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Six specimens, conditioned at 200°C (392°F) for 1000 hours, were constructed for each notch depth. The specimens were cut into lengths of six inches with a quarter inch of insulation removed from both ends and #10 ring terminals crimped on both conductor ends.

3.7.4.4 **Test Equipment:** This test utilized the notching tool described in Figure 1 of Metnod 707. The notch depths used are 5.7 mils (67% of 8.6 mils) and 4.3 mils (50% of 8.6 mils) for the 8.6 mil wall specimens and 3.9 mils (67% of 5.8 mils) and 2.9 mils (50% of 5.8 mils) for the 5.8 mil wall specimens. The notch depths were set and measured using a Nikon microscope (MD 115812) with a calibrated position sensor.

Mandrels approximately six times the diameter of the wire were manufactured for use in the wrapping segment of the test. The diameters used were 0.28125 inches for 22 gauge, 8.6 mil wall, airframe wire; 0.25 inches for 22 gauge, 5.8 mil wall, hook up wire; and 0.1875 for 26 gauge, 5.8 mil wall, hook up wire.

A Slaughter Dielectric Tester (MD 78995) was used to conduct the Voltage Withstand Test. The voltage was monitored by a Fluke 8050A Digital Multimeter (MD 011821) through a Fluke High Voltage Probe (MD 189698).

Photographs of the test setup and equipment are provided in Figures 3.33 through 3.34.

3.7.4.5 Test Procedure: The test was conducted by first securing the specimen to a steel plate to hold the wire secure during notching. The notching tool was placed upon the central portion of the wire and a black felt tip pen was used to mark the location of the tool on the specimen. The mark was necessary to identify the

location of the notch and to assist the operator in keeping the notch on the outside of the mandrel during wrapping. A 1.1 pound weight was placed on top of the tool, and the tool was pulled across the wire one time for a length of one inch of the blade and removed from the plate.

The wire was fastened to the appropriate mandrel on one end while the other had a one pound weight attached to apply tension during wrapping. With the notch constantly facing away from the mandrel, the wire was wound and unwound around the mandrel for one revolution prior to the notch (lengthwise) and one revolution following the notch (lengthwise) for 100 cycles (one cycle = one forward wind + one reverse wind) or until the conductor became visible. The specimen was wrapped around the mandrel at an approximate rate of 30 revolutions per minute. The specimen was removed from the mandrel and the number of cycles to failure was recorded.

The specimen was immersed in a 1% salt solution for a one minute soak time and subjected to a 2500 volt, 60 Hertz, Voltage Withstand Test. The voltage was applied at a rate of 500 volts per second and remained at 2500 volts for 10 seconds. A failure was defined as arcing at the notch or a leakage current greater than one milliamp.

The test was first conducted at the 66.67% notch depth. If any of the six specimens failed, the test was repeated with a notch depth at 50%. The results recorded the number of cycles to failure with a 100 cycle maximum and the results of the Voltage Withstand Test.

3.7.4.6 Test Results: The average number of cycles to failure and the results of the Voltage Withstand Tests are presented in Tables 3.64 through 3.66.

TABLE 3.64 - NOTCH PROPAGATION TEST RESULTS ON THERMALLY AGED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

		NOTCH DEPTH = 5.7 MILS		NOTCH DEPTH = 4.3 MILS	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	RESULTS OF VOLTAGE WITHSTAND (PASS/FAIL)	AVERAGE NUMBER OF CYCLES TO FAILURE	RESULTS OF VOLTAGE WITHSTAND (PASS/FAIL)
101	M81381	>100.0	6 / 0	------	-----
106	M22759	99.7	5 / 1	>100.0	6 / 0
111	BARCEL #1	>100.0	6 / 0	------	-----
116	BRAND REX #1	>100.0	6 / 0	------	-----
121	CHAMPLAIN #1	>100.0	6 / 0	------	-----
126	DUPONT #1	1 0	0 / 6	1.0	0 / 6
131	GORE #3	>100.0	6 / 0	------	-----
136	FILOTEX	>100.0	6 / 0	------	-----
141	TENSOLITE #3	>100.0	6 / 0	------	-----
146	THERMATICS #3	>100.0	6 / 0	------	-----
151	NEMA #2	>100 0	6 / 0	------	-----
156	NEMA #3	>100.0	6 / 0	------	-----

TABLE 3.65 - NOTCH PROPAGATION TEST RESULTS ON THERMAL AGED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

		NOTCH DEPTH = 3.9 MILS		NOTCH DEPTH = 2.9 MILS	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	RESULTS OF VOLTAGE WITHSTAND (PASS/FAIL)	AVERAGE NUMBER OF CYCLES TO FAILURE	RESULTS OF VOLTAGE WITHSTAND (PASS/FAIL)
102	M81381	>100.0	6 / 0	------	-----
107	M22759	84.8	1 / 5	>100.0	6 / 0
112	BARCEL #1	>100.0	6 / 0	------	-----
117	BRAND REX #1	>100.0	6 / 0	------	-----
122	CHAMPLAIN #1	>100.0	6 / 0	------	-----
127	DUPONT #1	1.0	0 / 6	1.0	0 / 6
132	GORE #3	>100.0	6 / 0	------	-----
137	FILOTEX	>100.0	6 / 0	------	-----
142	TENSOLITE #3	>100.0	6 / 0	------	-----
147	THERMATICS #3	>100.0	6 / 0	------	-----
152	NEMA #2	>100.0	6 / 0	------	-----
157	NEMA #3	>100.0	6 / 0	------	-----

TABLE 3.66 - NOTCH PROPAGATION TEST RESULTS ON THERMALLY AGED, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

		NOTCH DEPTH = 3.9 MILS		NOTCH DEPTH = 2.9 MILS	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	RESULTS OF VOLTAGE WITHSTAND (PASS/FAIL)	AVERAGE NUMBER OF CYCLES TO FAILURE	RESULTS OF VOLTAGE WITHSTAND (PASS/FAIL)
103	M81381	>100.0	6 / 0	------	-----
108	M22759	32.2	0 / 6	>100.0	6 / 0
113	BARCEL #1	>100.0	6 / 0	------	-----
118	BRAND REX #1	>100.0	6 / 0	------	-----
123	CHAMPLAIN #1	>100.0	6 / 0	------	-----
128	DUPONT #1	1.0	0 / 6	1.0	0 / 6
133	GORE #3	>100.0	6 / 0	------	-----
138	FILOTEX	>100.0	6 / 0	------	-----
143	TENSOLITE #3	>100.0	6 / 0	------	-----
148	THERMATICS #3	>100.0	6 / 0	------	-----
153	NEMA #2	>100.0	6 / 0	------	-----
158	NEMA #3	>100.0	6 / 0	------	-----

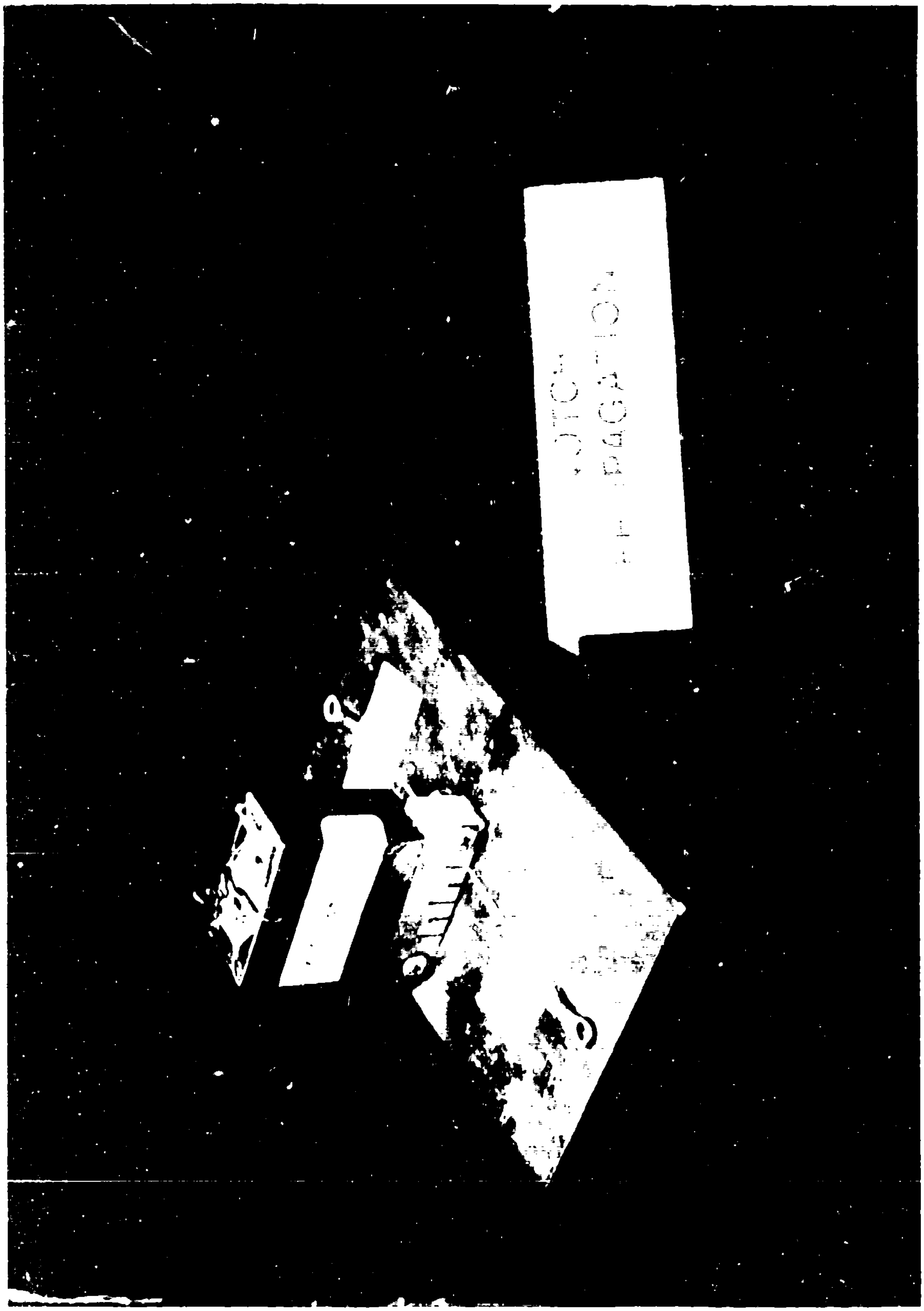


FIGURE 3.33 - NOTCH PROPAGATION TEST SETUP

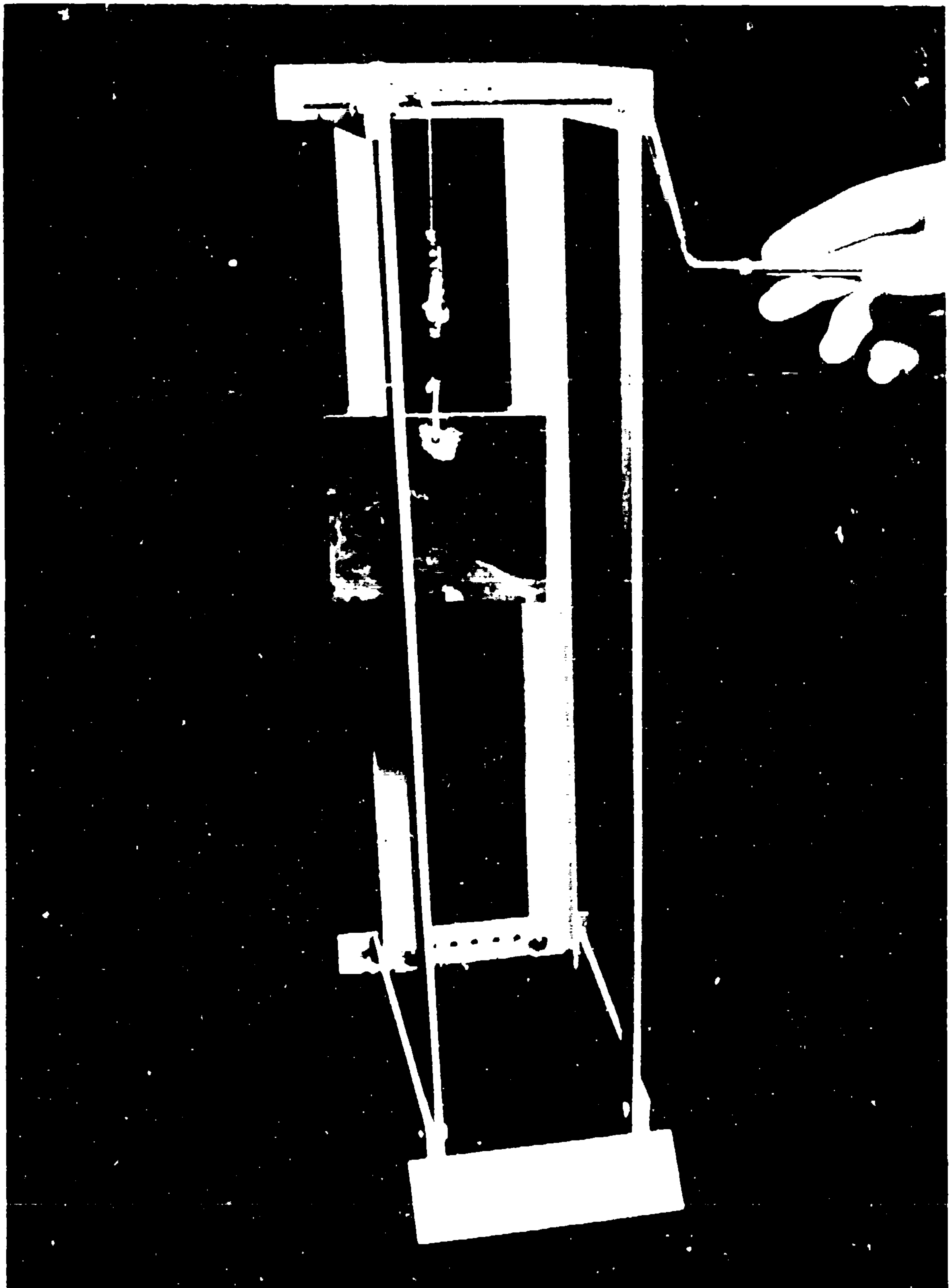


FIGURE 3.34 - NOTCH PROPAGATION TEST FIXTURE

3.7.5 STIFFNESS AND SPRINGBACK.

3.7.5.1 Scope: The Stiffness and Springback Test was used to generate data for comparison between samples using the same stiffness and springback apparatus. Stiffness and springback affect harness manufacturing, harness and cable installation, and maintenance operations.

3.7.5.2 Reference Procedure: The Stiffness and Springback Test was performed according to Method 708 of SAE AS4373.

3.7.5.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Six specimens of each sample were cut to a length of six inches and a spade terminal was crimped on the insulation and conductor at one end.

3.7.5.4 Test Equipment: The test fixture described in Method 708 was constructed to the appropriate dimensions. A 1.5 (T1-701-1.5) and 15 (T1-701-15) Autotronics inch-ounce torque meters were used to measure the stiffness of the specimen. A scale of 90° was imprinted on the plate of the fixture to determine the springback of the specimen from the 90° bent position.

A photograph of the test fixture is presented in Figure 3.37.

3.7.5.5 Test Procedure: The specimens were straightened by hand in an attempt to remove the natural curvature (reel set) of the wire due to the storage on the spools. The terminated end of the specimen was attached to the span selector which was set at a 4.0 inch length. The other end was routed through a hole in the center hub and an appropriate weight was attached to the specimen by use of an alligator clip. A 1.0 pound weight was attached to the 22 gauge specimens and a 0.5 pound weight was attached to the 26 gauge specimens. The specimen was twisted until the needle was perpendicular to the specimen. The torque meter was attached to the center hub and rotated clockwise until the wire was bent to a 90° angle. The T1-701-1.5 torque meter was used for torques less than 1.5 inch-ounces and the T1-701-15 torque meter was used for torques greater than 1.5 inch-ounces. At the 90° angle, the torque measurement was determined off the meter to acquire a stiffness value for the specimen. The wire was held at the 90° bent position for approximately 10 seconds. After the 10 second wait, the specimen was permitted to springback slowly until it achieved its final resting place. Springback was measured as the number of degrees that the arm moved from the 90° bent position to it's final resting position.

The stiffness and springback values were recorded to acquire an average stiffness and springback values for the sample. Higher inch-ounces indicates a stiffer material. Higher degrees indicates greater springback.

3.7.5.6 Test Results: The average stiffness and average springback values were calculated and presented in Tables 3.67 through 3.69 with graphical representation of the data provided in Figures 3.35 through 3.36.

TABLE 3.67 - STIFFNESS AND SPRINGBACK TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE STIFFNESS (INCH-OUNCES)	AVERAGE SPRINGBACK (DEGREES)
101	M81381	3.8	59
106	M22759	1.9	40
111	BARCEL #1	2.4	44
116	BRAND REX #1	2.1	47
121	CHAMPLAIN #1	2.5	42
126	DUPONT #1	3.2	38
131	GORE #3	2.2	20
136	FILOTEX	2.1	44
141	TENSOLITE #3	1.8	42
146	THERMATICS #3	2.6	43
151	NEMA #2	2.4	42
156	NEMA #3	2.3	42

TABLE 3.68 - STIFFNESS AND SPRINGBACK TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE STIFFNESS (INCH-OUNCES)	AVERAGE SPRINGBACK (DEGREES)
102	M81381	2.9	51
107	M22759	1.2	30
112	BARCEL #1	2.1	36
117	BRAND REX #1	1.8	37
122	CHAMPLAIN #1	2.1	39
127	DUPONT #1	2.7	35
132	GORE #3	1.8	18
137	FILOTEX	1.6	42
142	TENSOLITE #3	1.8	37
147	THERMATICS #3	2.0	37
152	NEMA #2	2.3	40
157	NEMA #3	1.8	42

TABLE 3.69 - STIFFNESS AND SPRINGBACK TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE STIFFNESS (INCH-OUNCES)	AVERAGE SPRINGBACK (DEGREES)
103	M81381	1.3	50
108	M22759	0.8	37
113	BARCEL #1	1.0	45
118	BRAND REX #1	1.2	48
123	CHAMPLAIN #1	1.0	45
128	DUPONT #1	1.3	44
133	GORE #3	0.7	29
138	FILOTEX	0.8	42
143	TENSOLITE #3	1.0	46
148	THERMATICS #3	0.8	43
153	NEMA #2	1.2	49
158	NEMA #3	0.8	45

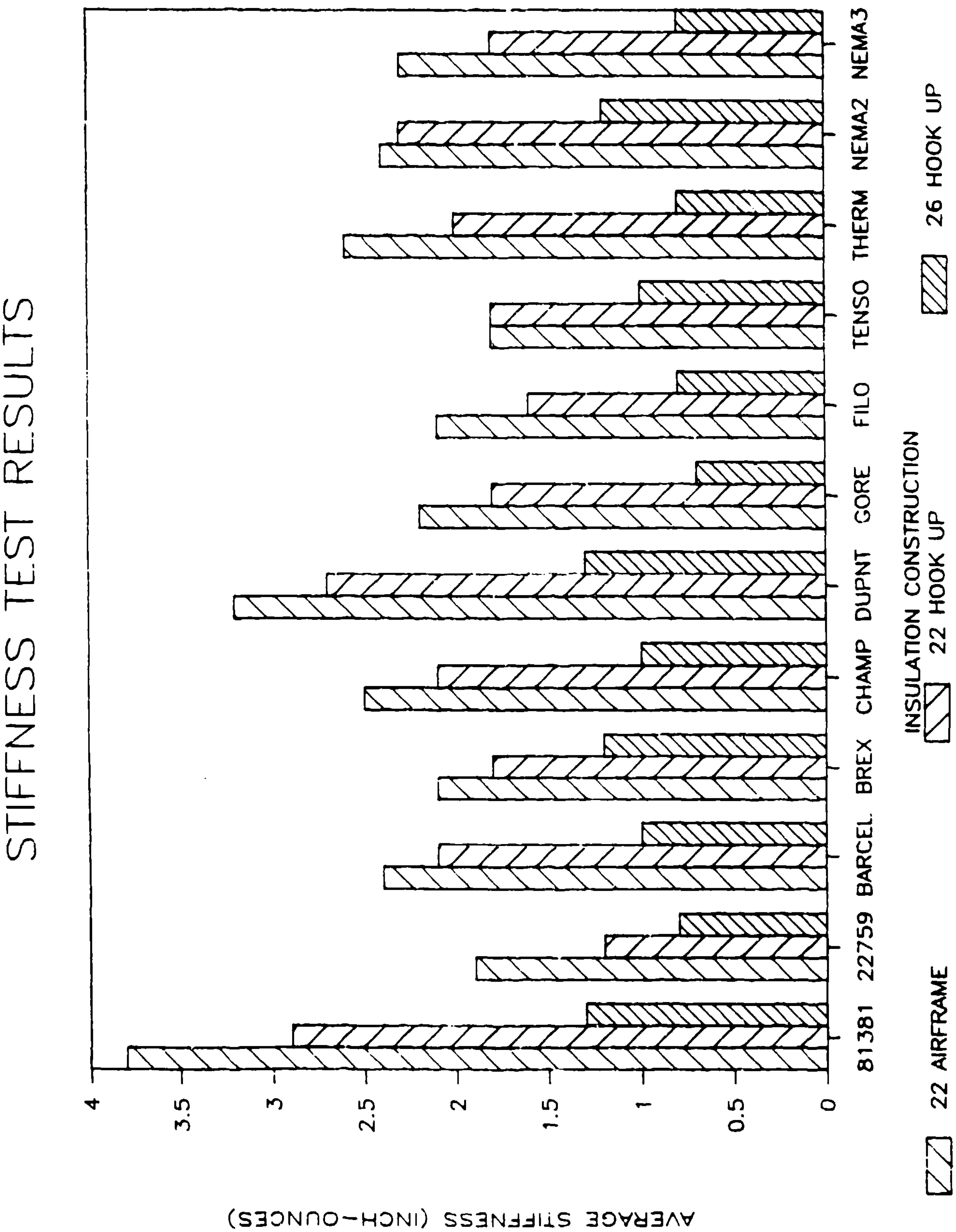


FIGURE 3.35 - STIFFNESS TEST RESULTS

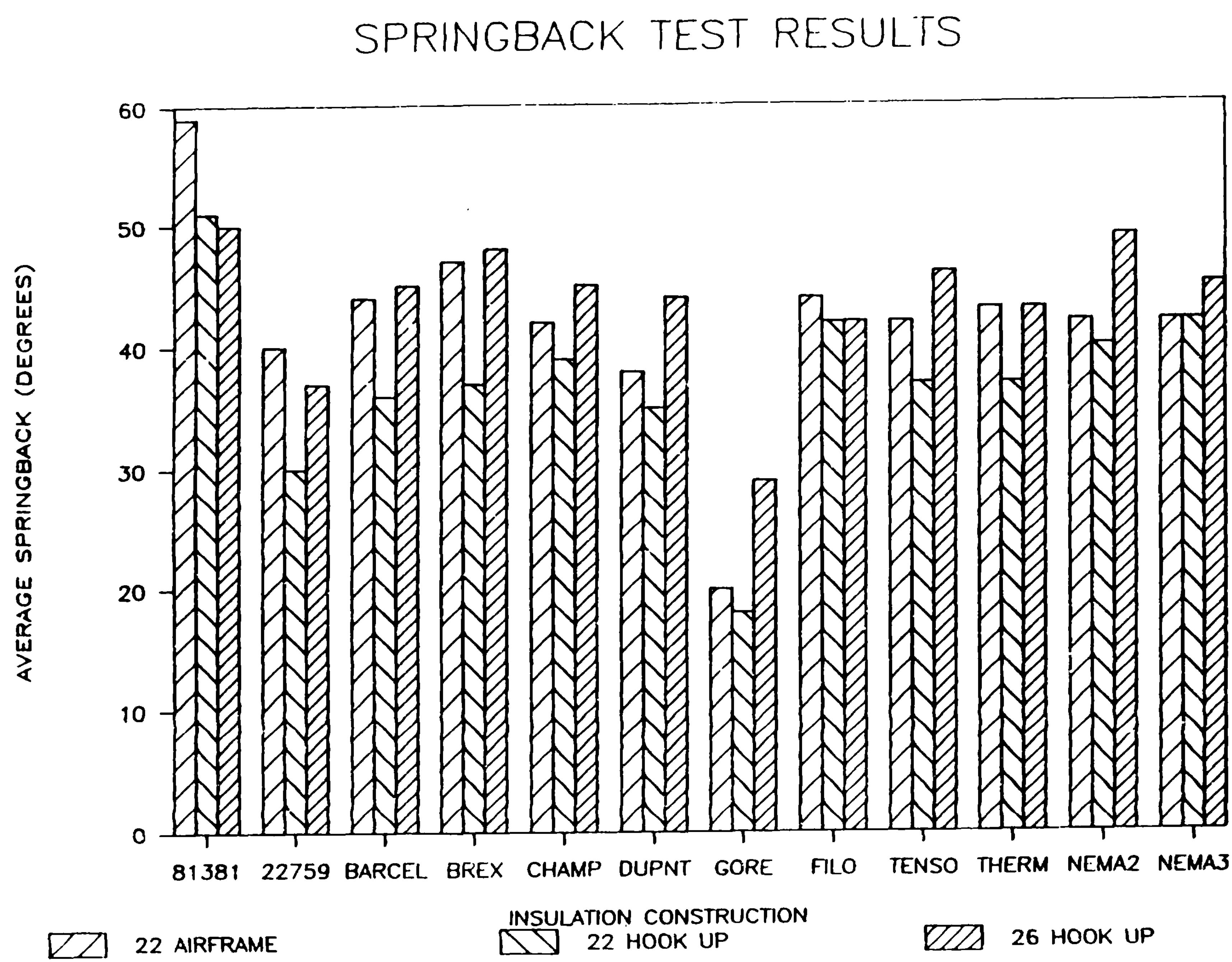


FIGURE 3.36 - SPRINGBACK TEST RESULTS

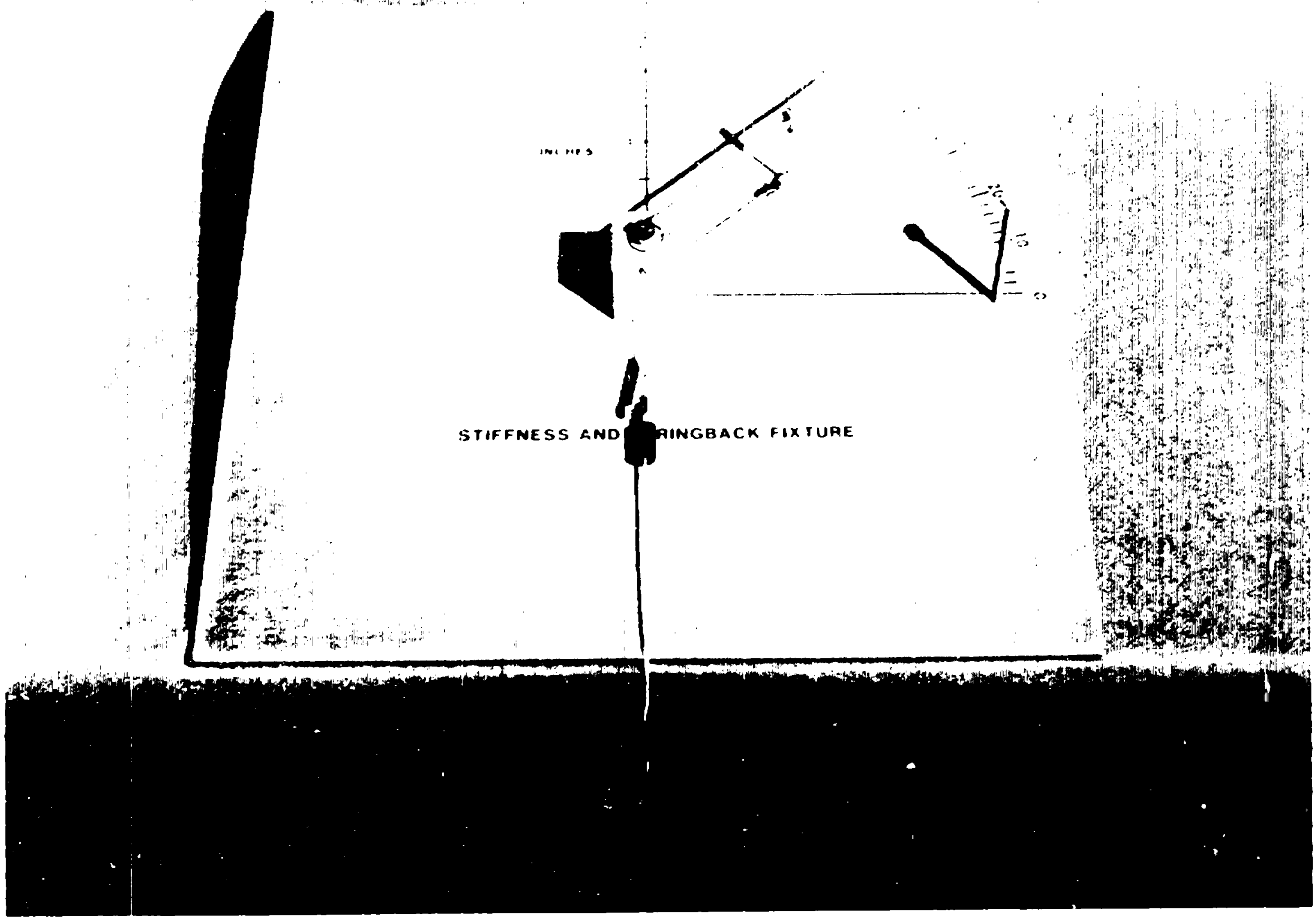


FIGURE 3.37 - STIFFNESS AND SPRINGBACK TEST SETUP

3.8 THERMAL TESTS

3.8.1 FLAMMABILITY.

3.8.1.1 Scope: The Flammability test evaluated a finished wire or cable sample's burning characteristics.

3.8.1.2 Reference Procedure: The Flammability Test was conducted according to Method 801 of SAE AS4373.

3.8.1.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 22 gauge, two conductor, twisted, shielded and jacketed cable. Six specimens of each sample were cut to a length of 24 inches. A quarter inch of insulation was removed from both ends of the specimen and #10 ring terminals were crimped on the conductor ends.

3.8.1.4 Test Equipment: A test chamber was constructed according to the specifications of Method 801 of SAE AS4373. The chamber was 24 (height) x 12 (depth) x 16 (width) inches. The chamber was housed under a vented hood to provide adequate ventilation. A clamp and pulley arrangement was set up inside the chamber to hold the specimen at a 60° angle to the horizontal. A three inch conical flame with a one inch cone was applied perpendicularly to the center of the specimen by a Bunsen

burner. The Bunsen burner was strapped to a ring stand and oriented such that the hottest point of the flame was directly on the specimen. Since propane gas was used, the flame temperature was 2200°F to 2500°F. A sheet of one ply facial tissue was placed approximately 9.5 inches under the specimen to catch falling droppings. A timer was included in the test set-up to record after flame and flame application.

The test was recorded on standard VHS tape for documentation of the test

Photographs of the test setup and equipment are presented in Figures 3.39 through 3.40.

3.8.1.5 Test Procedure: A specimen was placed into the set up with one end secured to the clamp and the other placed over the pulley and a weight attached. A 0.5 pound weight was used for the cable specimens while a 95 gram weight was used to keep the wire specimens taut. The vented hood exhaust fans were turned on, the VHS recorder was started, and the propane gas was ignited to commence the test. The flame was applied to the specimen for a period of 30 seconds. After the 30 second flame application, the propane gas was shut off to extinguish the flame. The data recorded was the length burned upward from the application point, length burned below the application point, duration of after flame, and if any tissue flaming occurred.

3.8.1.6 Test Results: The Filotex samples of 22 gauge, two conductor, twisted, shielded and jacketed cable were not tested because they were not available at the time of the test.

The number of specimens exhibiting an afterflame of approximately one second, length of insulation burned, and whether any tissue flaming occurred is presented in Tables 3.70 through 3.72 with graphical representation of the data provided in Figure 3.38.

TABLE 3.70 - FLAMMABILITY TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	NUMBER OF SPECIMENS EXHIBITING AFTERFLAME OF ~1 SEC.	INSULATION LENGTH BURNED (INCHES)			TISSUE FLAMING
			UP	DOWN	TOTAL	
101	M81381	0	1.50	0.50	2.00	NONE
106	M22759	3	2.13	0.63	2.76	NONE
111	BARCEL #1	0	1.58	0.50	2.08	NONE
116	BRAND REX #1	0	2.00	0.54	2.54	NONE
121	CHAMPLAIN #1	0	2.00	0.50	2.50	NONE
126	DUPONT #1	0	2.04	0.50	2.54	NONE
131	GORE #3	0	2.00	0.50	2.50	NONE
136	FILOTEX	0	1.58	0.50	2.08	NONE
141	TENSOLITE #3	0	1.54	0.50	2.04	NONE
146	THERMATICS #3	0	1.54	0.50	2.04	NONE
151	NEMA #2	0	2.04	0.50	2.54	NONE
156	NEMA #3	0	2.00	0.50	2.50	NONE

TABLE 3.71 - FLAMMABILITY TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	NUMBER OF SPECIMENS EXHIBITING AFTERFLAME OF ~1 SEC.	AVERAGE INSULATION LENGTH BURNED (INCHES)			TISSUE FLAMING
			UP	DOWN	TOTAL	
102	M81381	0	1.54	0.50	2.04	NONE
107	M22759	0	2.50	0.50	3.00	NONE
112	BARCEL #1	0	1.58	0.50	2.08	NONE
117	BRAND REX #1	0	2.00	0.71	2.71	NONE
122	CHAMPLAIN #1	1	1.96	0.71	2.67	NONE
127	DUPONT #1	0	1.92	0.54	2.46	NONE
132	GORE #3	0	2.00	0.50	2.50	NONE
137	FILOTEX	0	1.67	0.50	2.17	NONE
142	TENSOLITE #3	0	1.46	0.50	1.96	NONE
147	THERMATICS #3	0	1.88	0.54	2.42	NONE
152	NEMA #2	0	2.04	0.67	2.71	NONE
157	NEMA #3	0	2.04	0.50	2.54	NONE

TABLE 3.72 - FLAMMABILITY TEST RESULTS ON 22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	NUMBER OF SPECIMENS EXHIBITING AFTERFLAME OF ~1 SEC.	AVERAGE INSULATION LENGTH BURNED (INCHES)			TISSUE FLAMING
			UP	DOWN	TOTAL	
104	M81381	0	1.67	0.50	2.17	NONE
109	M22759	5	1.88	0.50	2.38	NONE
114	BARCEL #1	0	1.50	0.50	2.00	NONE
119	BRAND REX #1	0	2.08	0.75	2.83	NONE
124	CHAMPLAIN #1	0	2.00	0.54	2.54	NONE
129	DUPONT #1	0	1.71	0.50	2.21	NONE
134	GORE #3	2	1.54	0.50	2.04	NONE
139	FILOTEX	---	----	----	----	----
144	TENSOLITE #3	1	1.50	0.50	2.00	NONE
149	THERMATICS #3	0	1.58	0.50	2.08	NONE
154	NEMA #2	0	1.92	0.50	2.42	NONE
159	NEMA #3	0	2.08	0.79	2.87	NONE

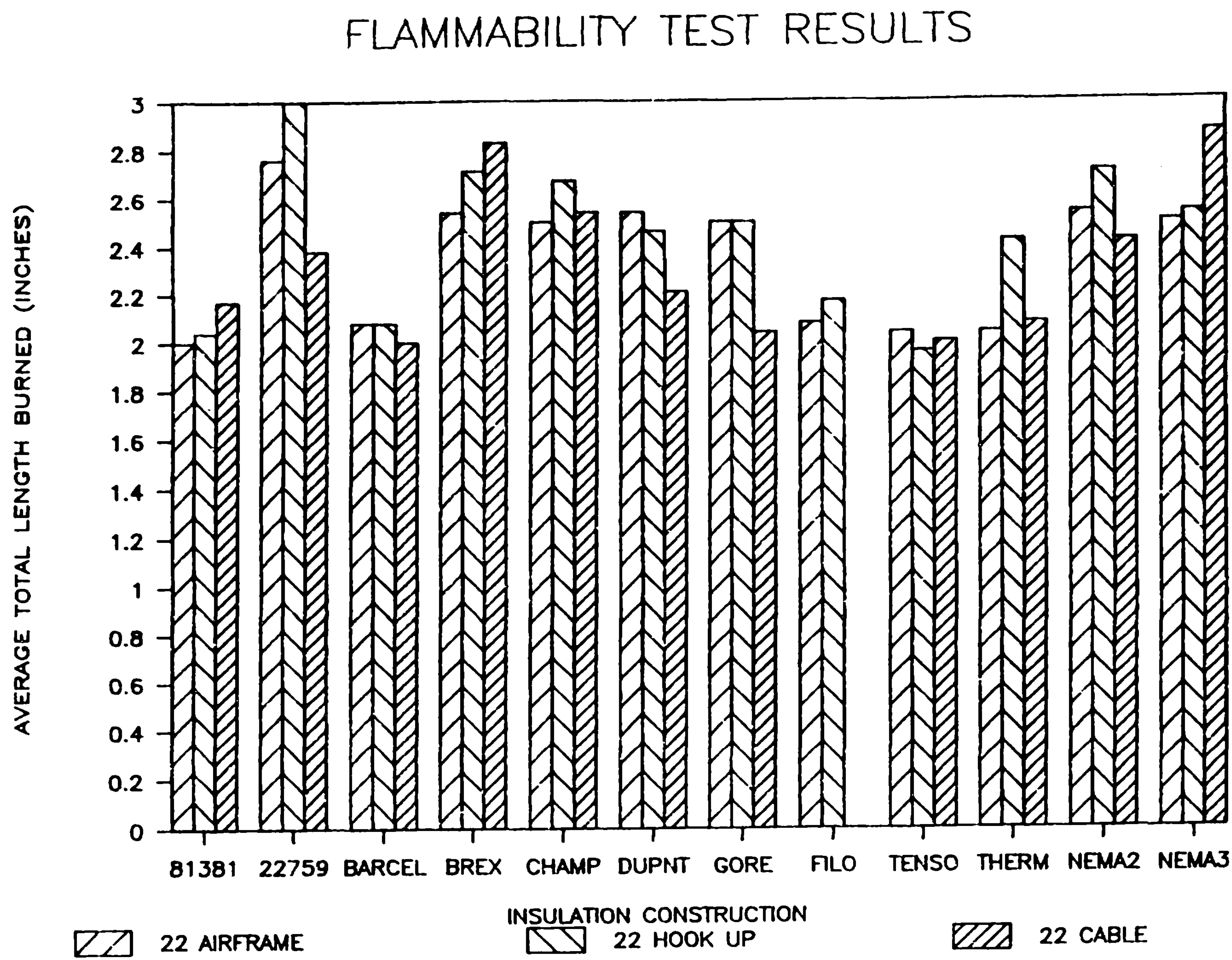


FIGURE 3.38 - FLAMMABILITY TEST RESULTS

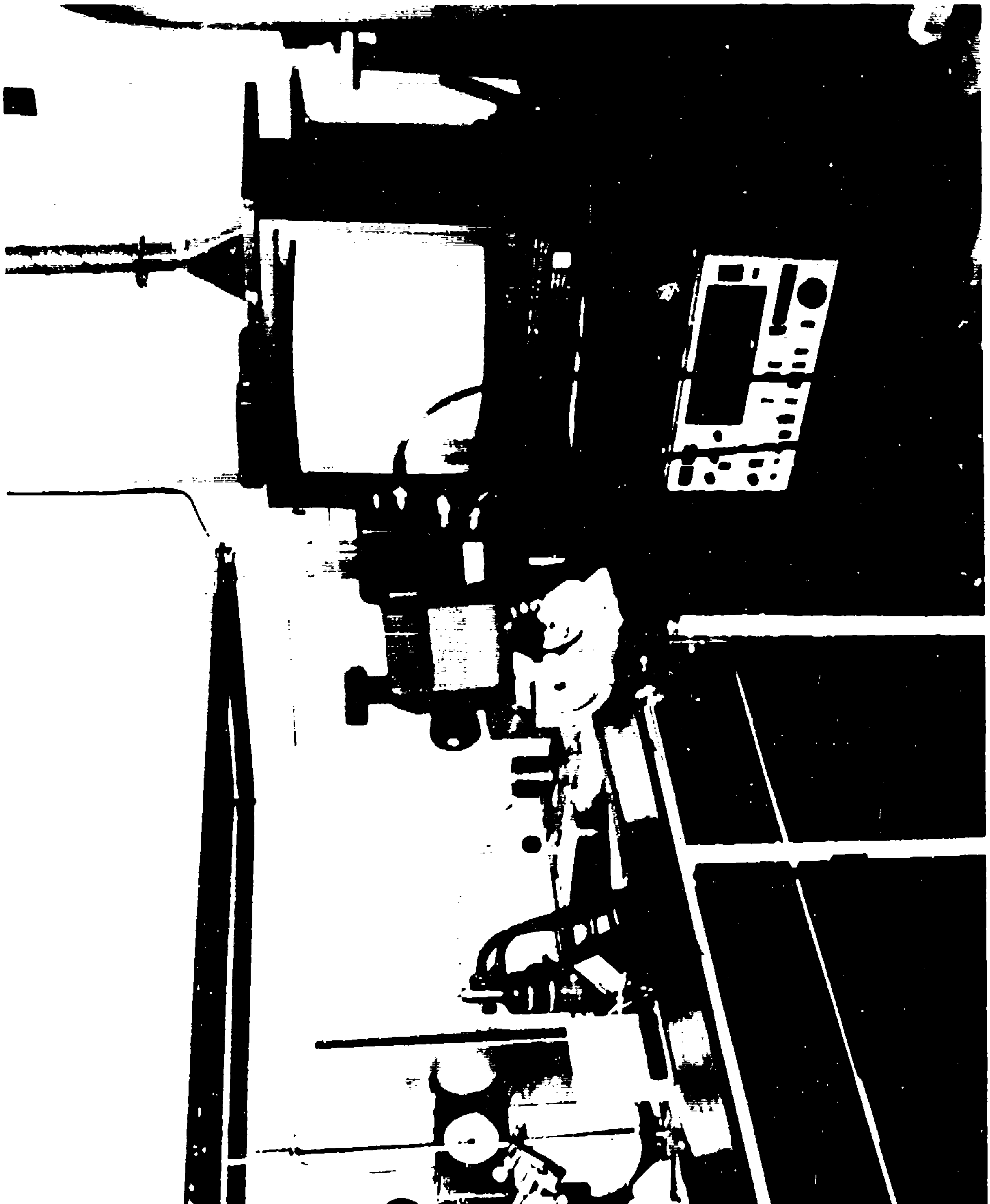


FIGURE 3.39 - FLAMMABILITY TEST SETUP

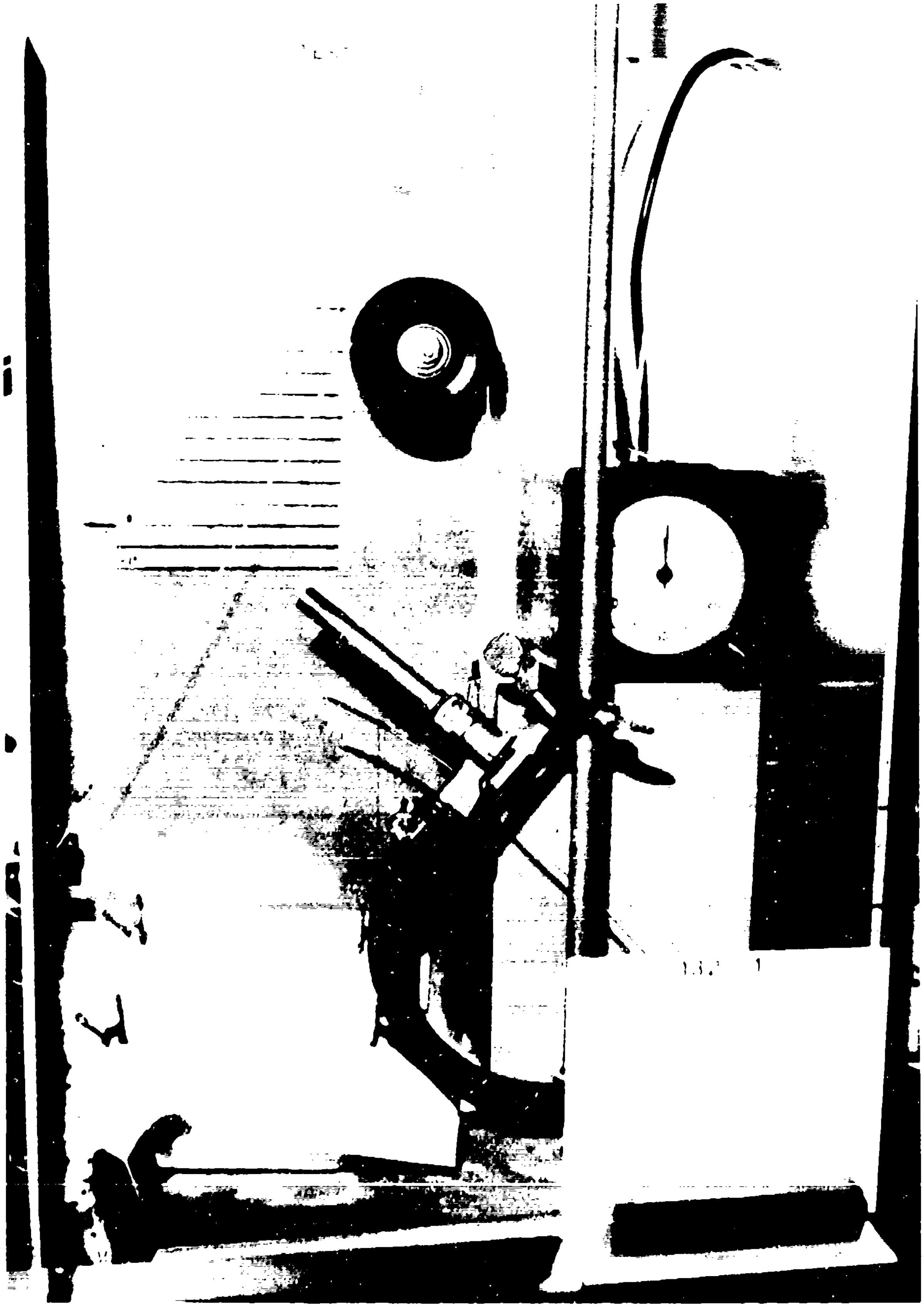


FIGURE 3.40 - FLAMMABILITY TEST SETUP

3.8.2 TOXICITY.

3.8.2.1 Scope: The Toxicity Test was used to evaluate an insulation's outgassing of certain dangerous compounds when the sample was burned.

3.8.2.2 Reference Procedure: The Toxicity Test was performed according to the test procedure outlined in MDC Report B0482, which references Naval Engineering Standard (NES) 713, Issue 2, since Method 806 of SAE AS4373 does not exist.

3.8.2.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 22 gauge, two conductor, twisted, shielded and jacketed cable. The length of specimens was determined by burning a particular length for one minute to achieve a 1.0 to 2.0 gram burn mass. The resulting lengths determined were 96 inches for the cable specimens and 120 inches for the wire specimens. Three specimens were tested for each sample. The specimens were conditioned at 23±2°C at 50% relative humidity for 24 hours prior to the test. The specimens were coiled into the form of a figure "8" and placed into the specimen holding coil. See figure 3.43.

3.8.2.4 Test Equipment: A 0.81 cubic meter (volume) chamber was used with internal mixing fans and exhaust system to house the test set-up. The chamber conformed to the specifications outlined in NES 713. The Bunsen burner used propane gas to facilitate combustion. The burner was positioned 45±2 millimeters from the bottom edge of the specimen. The flame was applied at a 30° angle to the vertical with a 40 millimeter inner blue cone. A Pyrex dish of measured mass was placed under the specimen to catch any drippings during the test. The chamber was connected to a compressed air line to purge the chamber after completion of each test.

A thermometer and barometer were used to measure test temperature and humidity prior to each test.

The methods used to detect the various gases specified are listed in Table 3.73. Pumps for the detector tubes were leak checked at the beginning of each test day.

TABLE 3.73 - TOXICITY MEASURING METHODS

GASEOUS COMPOUND	MEASURING METHOD
Carbon Dioxide	Detector Tube
Carbon Monoxide	Detector Tube
Formaldehyde	Detector Tube
Nitrogen Dioxide	Infrared Spectroscopy
Nitric Oxide	Detector Tube
Hydrogen Cyanide	Specific Ion Electrode
Acrylontrile	Gas Chromography/Mass Spectrum
Sulfur Dioxide	Infrared Spectroscopy
Hydrogen Sulfide	Detector Tube
Hydrogen Chloride	Specific Ion Electrode
Ammonia	Detector Tube
Hydrogen Fluoride	Specific Ion Electrode
Hydrogen Bromide	Specific Ion Electrode

Photographs of the test setup and equipment are presented in Figures 3.42 through 3.45.

3.8.2.5 Test Procedure: A background check was conducted periodically on an empty chamber for one and two minute burn times to check for carbon monoxide and carbon dioxide build-up on the chamber walls. These values are subtracted from the raw data values to acquire the final test results.

The test was initiated by weighing the specimen, holder, and Pyrex dish to the nearest milligram (except cable specimens which were measured to the nearest hundredth). The specimen and holder were placed inside the test chamber, the Pyrex dish was placed beneath the specimen, the door was sealed, and the vent was closed. The flame was ignited and applied for either a one minute or two minute burn time to acquire a 1.0 to 2.0 gram burn mass. The gas was shut off and the flame was allowed to extinguish. The mixing fans were applied for 30 seconds before samples of the gases were extracted from the chamber. The chamber temperature and humidity were also recorded at this time. After the extraction of samples was completed, the chamber was purged using compressed air for a minimum of 5 minutes. The door was opened and the specimen was weighed along with the Pyrex dish to determine the test burn mass. The test burn mass and the concentration of each gas detected were recorded. Using

the formula below, the concentration value of each gas detected was normalized to a 100 gram burn mass diffused in air in a volume of one cubic meter.

$$C_{\emptyset} = ((c \times 100) \times v) / m \quad \text{parts per million}$$

$C_{\emptyset}$ = normalized concentration of gas
c = concentration of gas detected in chamber (parts per million)
m = test burn mass (grams)
v = volume of test chamber (cubic meters)

The ratio between the normalized concentration detected to the concentration of the gas considered to be fatal to a man for a 30 minute exposure, in parts per million, was calculated. The summation of each of these ratios is called the toxicity index.

$$T = \sum_{1}^{n} (C_{\emptyset 1} / C_{f1}) + \ldots\ldots\ldots + (C_{\emptyset n} / C_{fn})$$

T = toxicity index
C_f = concentration of the gas considered fatal to a man for a 30 minute exposure (parts per million).

The calculated toxicity index of that specimen was determined by Section 10 and Annex A of NES 713, Issue 2. A higher number indicates a higher level of toxicity.

3.8.2.6 Test Results: The Toxicity Index of each of the specimens tested is presented in Tables 3.74 through 3.76 with a graphical representation of the data provided in Figure 3.41.

TABLE 3.74 - TOXICITY TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	TOXICITY INDEX (AVG. OF 3 SPECIMENS)
101	M81381	93.46
106	M22759	48.53
111	BARCEL #1	39.76
116	BRAND REX #1	47.29
121	CHAMPLAIN #1	40.23
126	DUPONT #1	35.48
131	GORE #3	41.00
136	FILOTEX	34.59
141	TENSOLITE #3	80.34
146	THERMATICS #3	30.22
151	NEMA #2	62.43
156	NEMA #3	27.68

TABLE 3.75 - TOXICITY TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	TOXICITY INDEX (AVG. OF 3 SPECIMENS)
102	M81381	45.62
107	M22759	37.40
112	BARCEL #1	170.87
117	BRAND REX #1	65.73
122	CHAMPLAIN #1	71.14
127	DUPONT #1	28.82
132	GORE #3	88.72
137	FILOTEX	35.79
142	TENSOLITE #3	38.38
147	THERMATICS #3	62.85
152	NEMA #2	136.88
157	NEMA #3	99.31

TABLE 3.76 - TOXICITY TEST RESULTS ON
22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	TOXICITY INDEX (AVG. OF 3 SPECIMENS)
104	M81381	37.14
109	M22759	51.91
114	BARCEL #1	59.68
119	BRAND REX #1	42.65
124	CHAMPLAIN #1	34.90
129	DUPONT #1	31.37
134	GORE #3	106.97
139	FILOTEX	------
144	TENSOLITE #3	64.85
149	THERMATICS #3	75.35
154	NEMA #2	96.70
159	NEMA #3	63.97

NES 713 required statement. "This test result alone does not assess the fire hazard of the material, or a product made from this material, under actual fire conditions. Consequently the results of this test alone shall not be quoted in support of claims with respect to the fire hazard of the material or product under actual fire conditions. Tho results when used alone should only be used for research and development, quality control, and material specification."

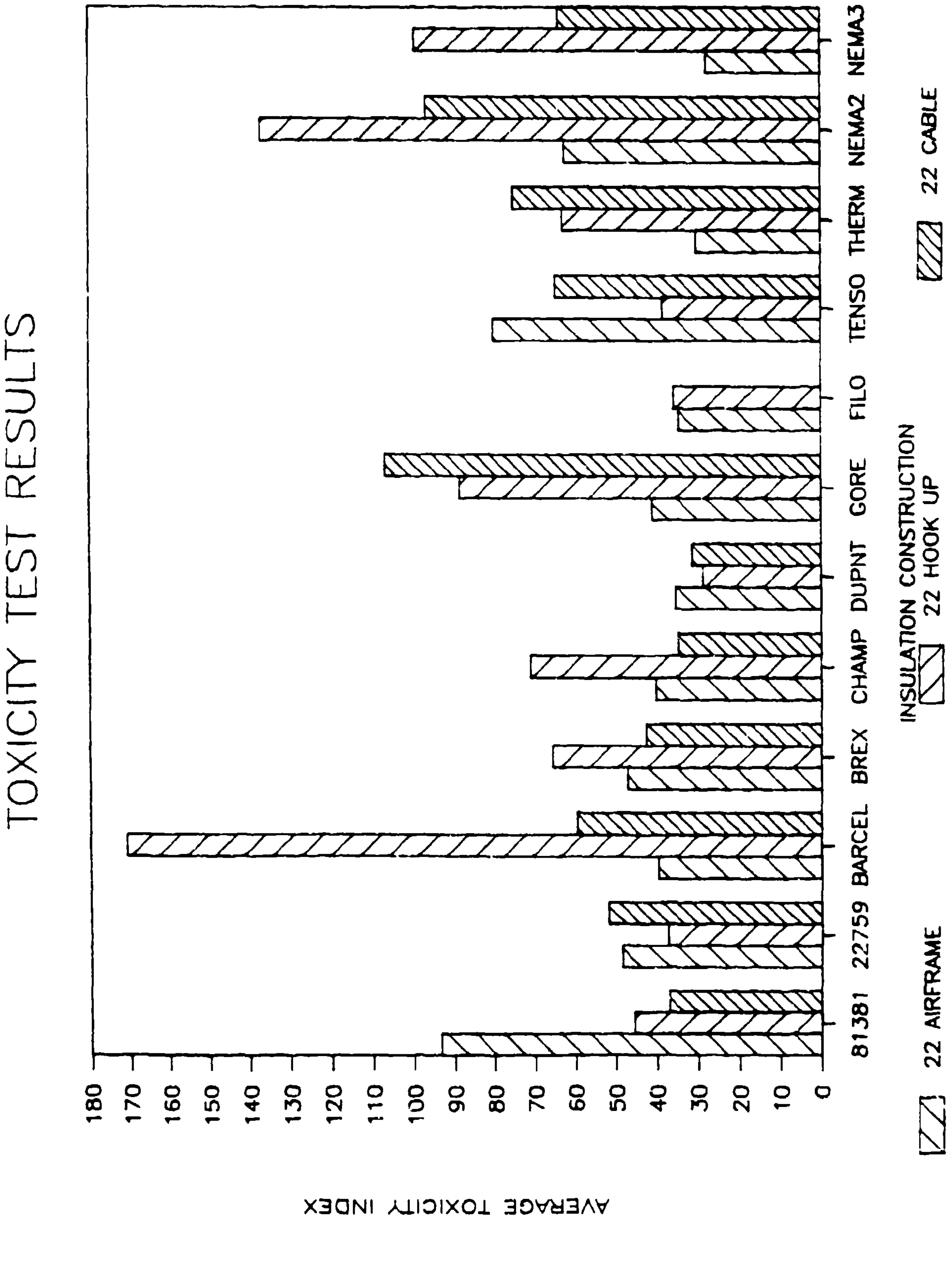


FIGURE 3.41 - TOXICITY TEST RESULTS

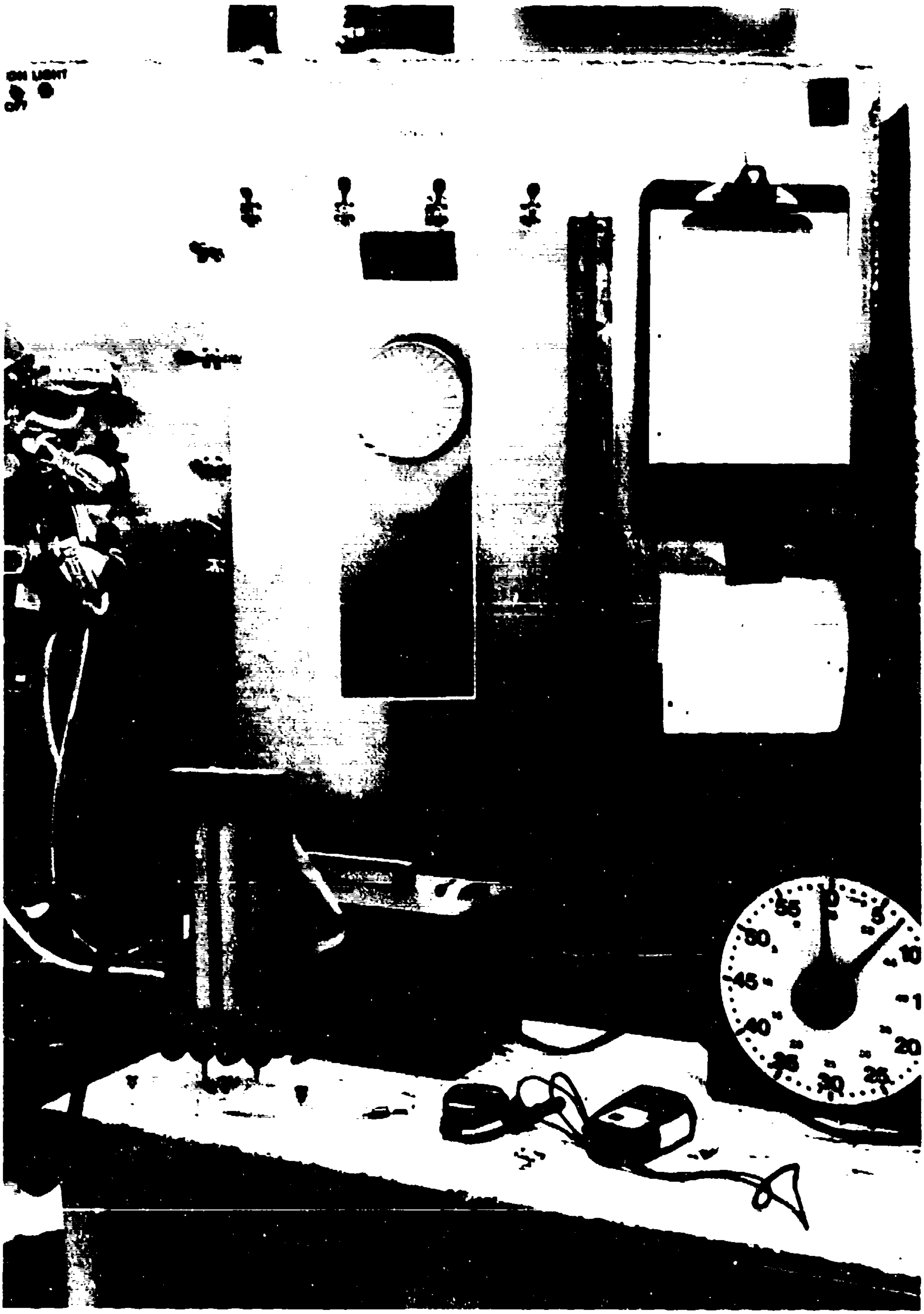


FIGURE 3.42 - TOXICITY TEST CHAMBER

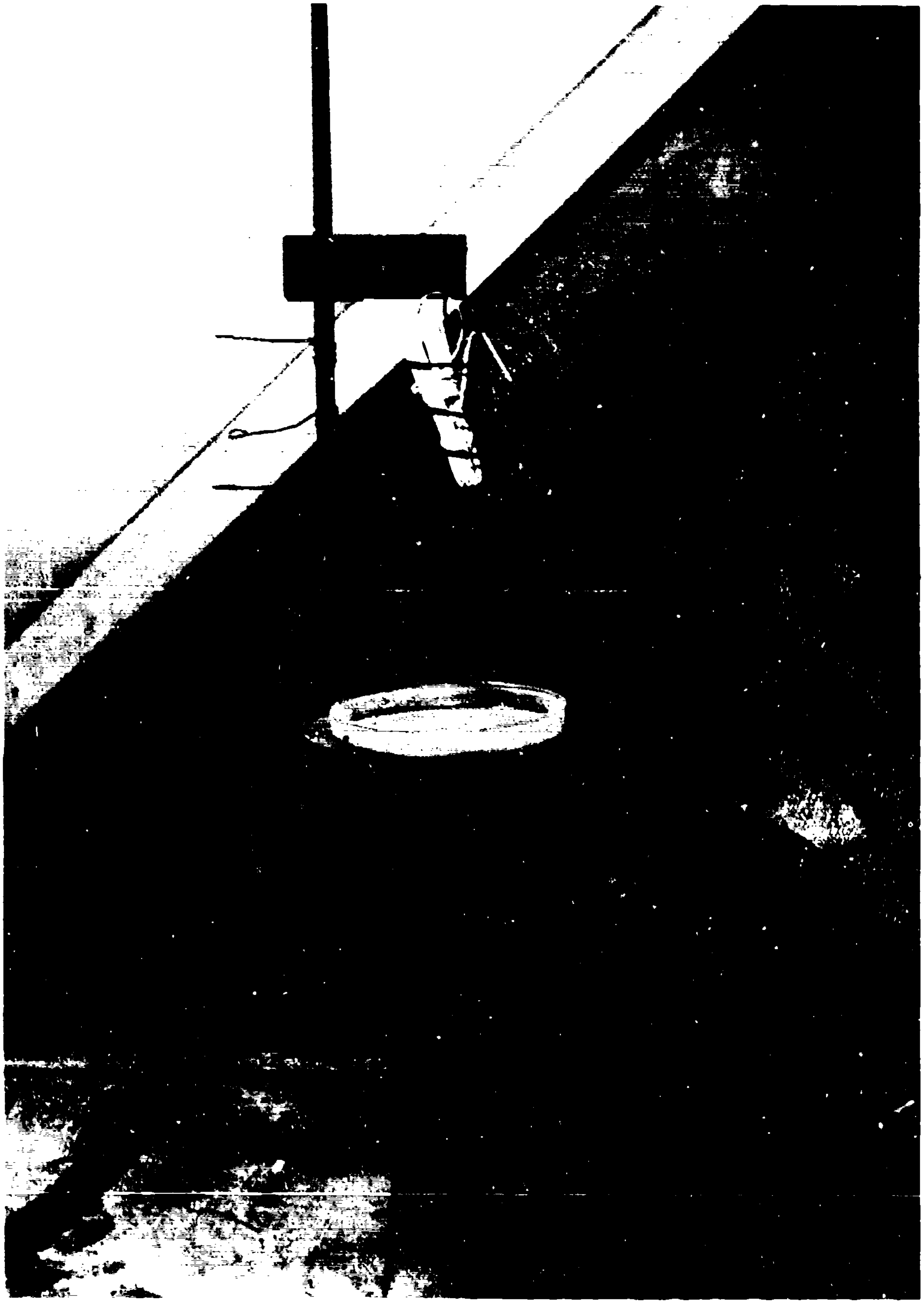


FIGURE 3.43 - TOXICITY TEST SETUP

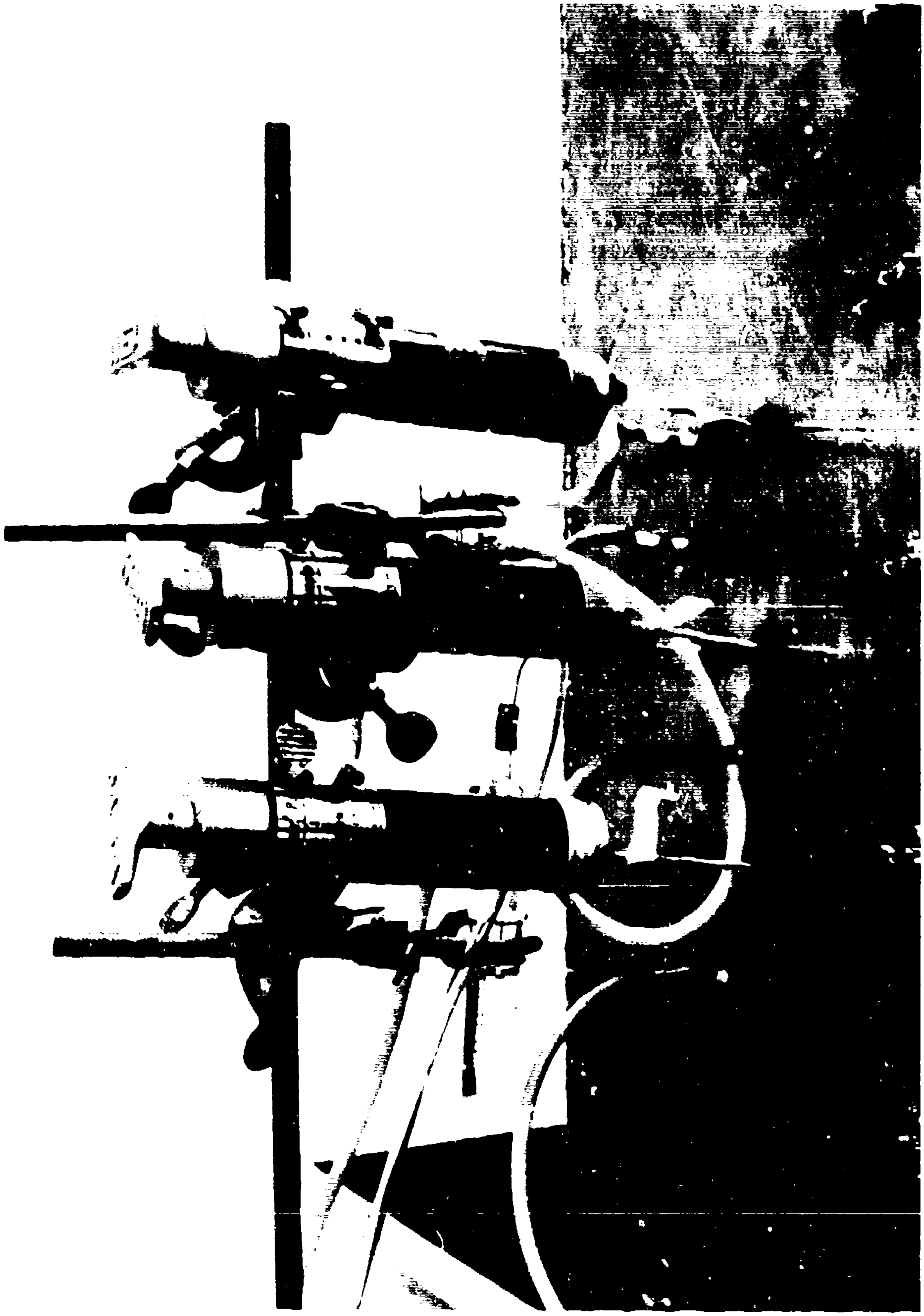


FIGURE 3.44 - TOXICITY DETECTOR TUBES

3.9 WIRE DIAMETER AND WEIGHT TESTS

3.9.1 FINISHED DIAMETER.

3.9.1.1 FINISHED WIRE DIAMETER.

3.9.1.1.1 Scope: The Finished Wire Diameter Test was used to determine the average finished wire sample diameter.

2 Reference Procedure: The Finished Wire Diameter Test was conducted using Method 901 of SAE AS4373. Method 901 references section 15 of ASTM D3032 for precision of instrument and procedure.

3.9.1.1.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. A 26 inch specimen was cut from each end of the spool with one inch of insulation removed from both ends of the specimen for conductor measurements.

3.9.1.1.4 Test Equipment: An L.S. Starett Micrometer Caliper (MD 66-1-291) calibrated to 0.0003 inches was used to conduct the diameter measurements.

3.9.1.1.5 Test Procedure: The specimens were measured with a micrometer at the 7 inch, 13 inch, and the 19 inch points on the specimen. Each point of measurement consisted of two micrometer readings, with the second reading 90° from the first reading. A total of six measurements were acquired from each specimen.

These measurements were averaged together to acquire an average finished wire diameter value for the sample.

3.9.1.1.6 Test Results: The maximum, minimum, and average finished wire diameters are presented in Tables 3.77 through 3.79 with a graphical representation of the data provided in Figures 3.45 through 3.48.

TABLE 3.77 - FINISHED WIRE DIAMETER TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	FINISHED WIRE DIAMETER (INCHES) MINIMUM	MAXIMUM	AVERAGE
101	M81381	0.0454	0.0475	0.0466
106	M22759	0.0472	0.0498	0.0485
111	BARCEL #1	0.0448	0.0452	0.0450
116	BRAND REX #1	0.0442	0.0461	0.0451
121	CHAMPLAIN #1	0.0486	0.0497	0.0492
126	DUPONT #1	0.0450	0.0469	0.0460
131	GORE #3	0.0470	0.0477	0.0474
136	FILOTEX	0.0445	0.0454	0.0450
141	TENSOLITE #3	0.0474	0.0479	0.0476
146	THERMATICS #3	0.0449	0.0454	0.0452
151	NEMA #2	0.0460	0.0471	0.0467
156	NEMA #3	0.0450	0.0465	0.0457

TABLE 3.78 - FINISHED WIRE DIAMETER TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	FINISHED WIRE DIAMETER (INCHES) MINIMUM	MAXIMUM	AVERAGE
102	M81381	0.0395	0.0415	0.0408
107	M22759	0.0398	0.0406	0.0403
112	BARCEL #1	0.0413	0.0424	0.0419
117	BRAND REX #1	0.0390	0.0409	0.0398
122	CHAMPLAIN #1	0.0415	0.0428	0.0420
127	DUPONT #1	0.0405	0.0424	0.0415
132	GORE #3	0.0406	0.0419	0.0412
137	FILOTEX	0.0390	0.0398	0.0394
142	TENSOLITE #3	0.0433	0.0446	0.0439
147	THERMATICS #3	0.0403	0.0408	0.0405
152	NEMA #2	0.0418	0.0431	0.0427
157	NEMA #3	0.0414	0.0417	0.0416

TABLE 3.79 - FINISHED WIRE DIAMETER TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	FINISHED WIRE DIAMETER (INCHES) MINIMUM	MAXIMUM	AVERAGE
103	M81381	0.0295	0.0300	0.0298
108	M22759	0.0300	0.0310	0.0306
113	BARCEL #1	0.0306	0.0309	0.0307
118	BRAND REX #1	0.0326	0.0342	0.0334
123	CHAMPLAIN #1	0.0326	0.0334	0.0330
128	DUPONT #1	0.0300	0.0318	0.0308
133	GORE #3	0.0285	0.0297	0.0290
138	FILOTEX	0.0289	0.0293	0.0291
143	TENSOLITE #3	0.0333	0.0347	0.0341
148	THERMATICS #3	0.0295	0.0300	0.0298
153	NEMA #2	0.0338	0.0345	0.0341
158	NEMA #3	0.0308	0.0317	0.0313

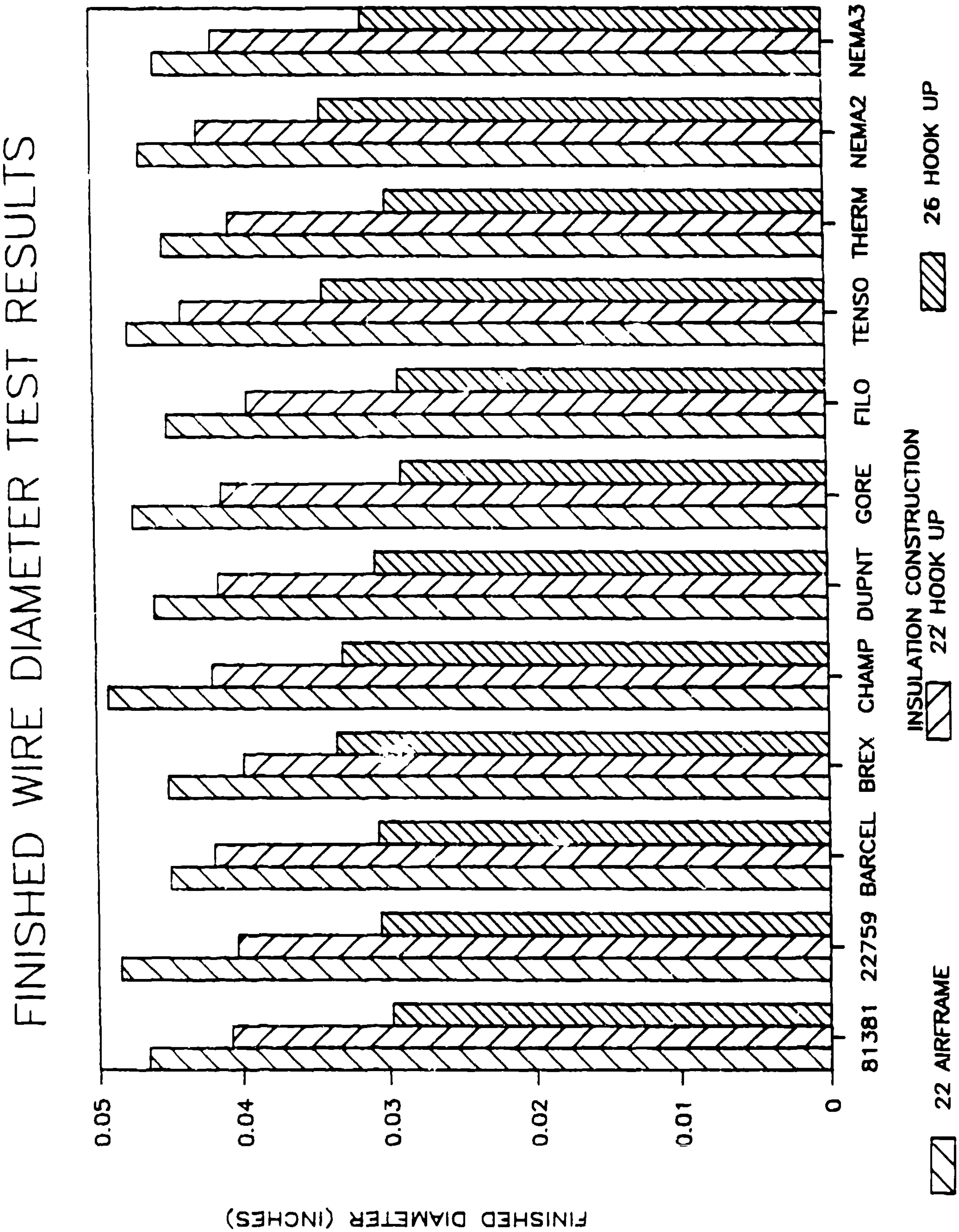


FIGURE 3.45 - FINISHED WIRE DIAMETER TEST RESULTS

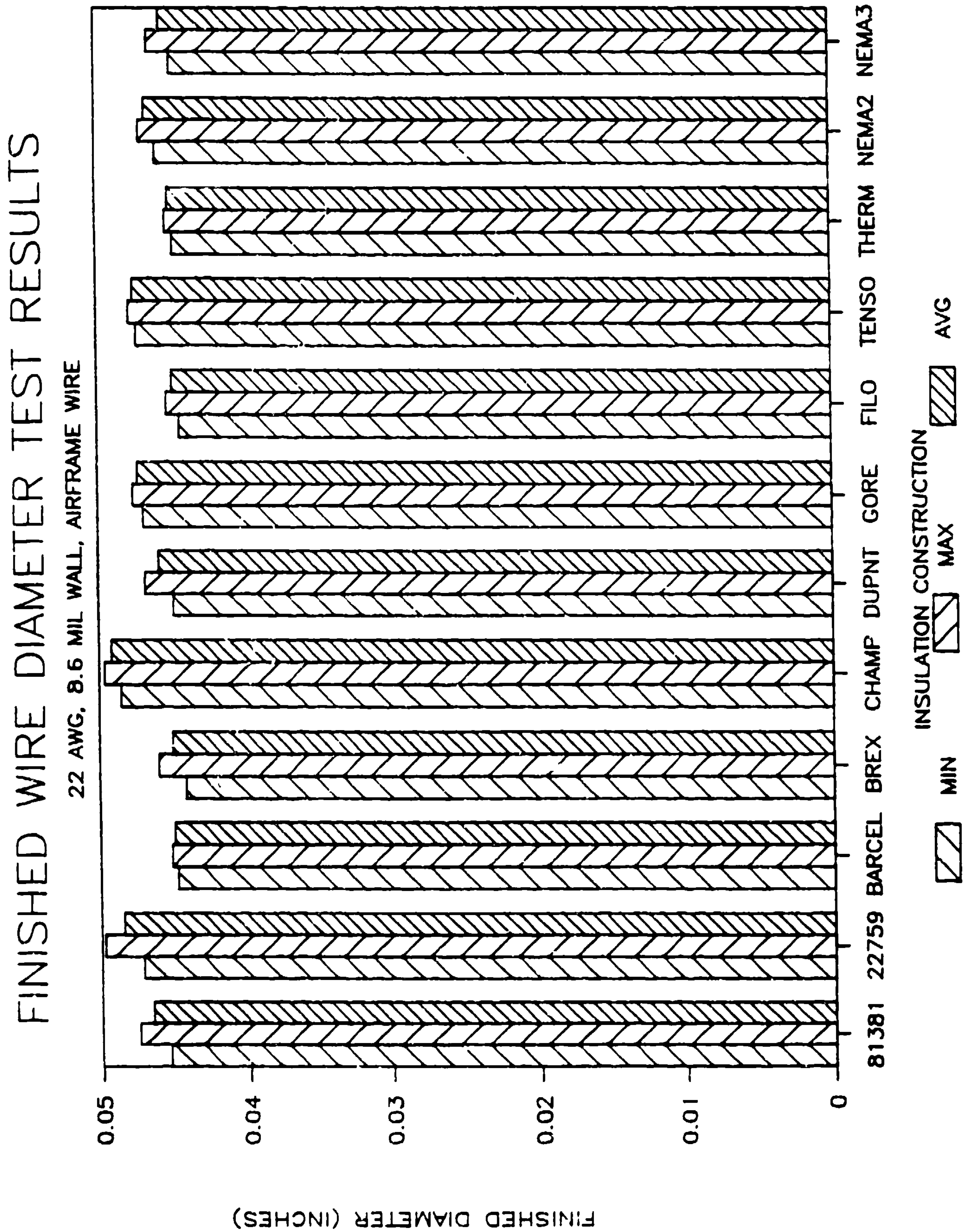


FIGURE 3.46 - FINISHED WIRE DIAMETER TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

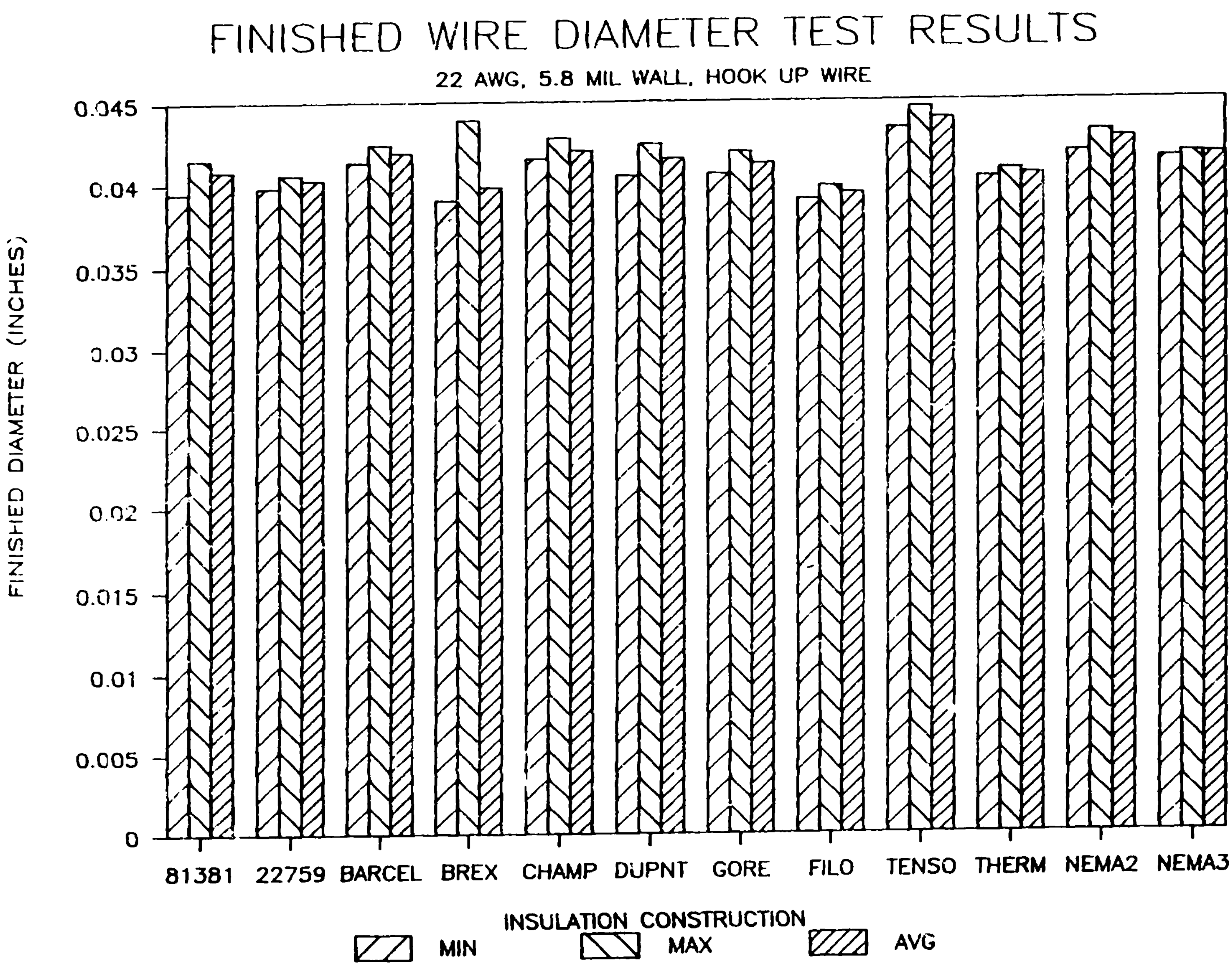


FIGURE 3.47 - FINISHED WIRE DIAMETER TEST RESULTS,
22AWG, 5.8 MIL WALL, HOOK UP WIRE

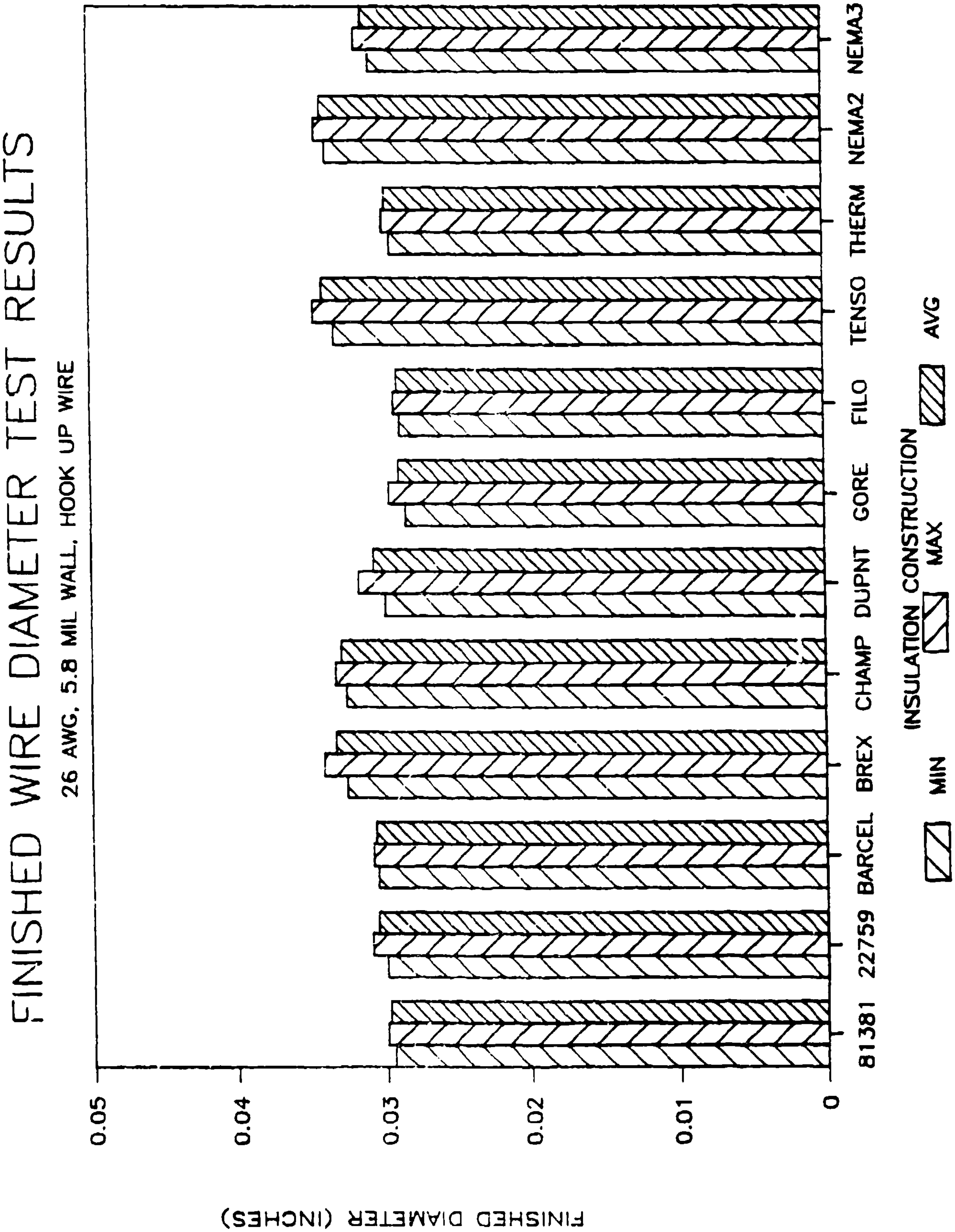


FIGURE 3.48 - FINISHED WIRE DIAMETER TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

3.9.1.2 FINISHED CABLE DIAMETER.

3.9.1.2.1 Scope: The Finished Cable Diameter Test was used to determine the average maximum, minimum, and overall finished cable diameter.

3.9.1.2.2 Reference Procedure: The Finished Cable Diameter Test was conducted using Method 901 of SAE AS4373 as a guide. Method 901 references section 15 of ASTM D3032 for precision of instrument and procedure.

3.9.1.2.3 Specimens: Specimens were constructed for 22 and 26 gauge, two conductor, twisted, shielded and jacketed cable. A 26 inch specimen was cut from each end of the spool.

3.9.1.2.4 Test Equipment: An L.S. Starett Micrometer Caliper (MD 66-1-291) calibrated to 0.0003 inches was used to conduct the diameter measurements.

3.9.1.2.5 Test Procedure: The specimens were measured with a micrometer at the 7 inch, 13 inch, and the 19 inch points on the specimen. Each point of measurement consisted of two micrometer readings, to determine the maximum and minimum cable diameter. A total of six measurements were acquired from each specimen. The six maximum values obtained were averaged together to acquire an average

finished maximum cable diameter while the six minimum measurements were used to determine the average minimum finished cable diameter. The average overall cable diameter was determined from by the summation of the average maximum and minimum cable diameters divided by two.

Each individual measurement was recorded and the average minimum, maximum, and overall diameters of the finished cable samples were calculated.

3.9.1.2.6 Test Results: The average maximum, average minimum, and average overall diameter of the Finished Cable Diameters are presented in Tables 3.80 through 3.81 with a graphical representation of the data provided in Figures 3.49 through 3.51.

TABLE 3.80 - FINISHED CABLE DIAMETER TEST RESULTS ON 22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	FINISHED CABLE DIAMETER (INCHES) AVERAGE MINIMUM	AVERAGE MAXIMUM	AVERAGE OVERALL
104	M81381	0.0602	0.0952	0.0777
109	M22759	0.0610	0.0926	0.0768
114	BARCEL #1	0.0603	0.0922	0.0763
119	BRAND REX #1	0.0608	0.0973	0.0790
124	CHAMPLAIN #1	0.0679	0.0994	0.0836
129	DUPONT #1	0.0737	0.0981	0.0859
134	GORE #3	0.0737	0.0972	0.0855
239	FILOTEX	0.0709	0.0947	0.0828
144	TENSOLITE #3	0.0713	0.1070	0.0891
149	THERMATICS #3	0.0725	0.0957	0.0841
154	NEMA #2	0.0753	0.0952	0.0853
159	NEMA #3	0.0703	0.0952	0.0827

TABLE 3.81 - FINISHED CABLE DIAMETER TEST RESULTS ON 26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	FINISHED CABLE DIAMETER (INCHES) AVERAGE MINIMUM	AVERAGE MAXIMUM	AVERAGE OVERALL
105	M81381	0.0559	0.0738	0.0649
110	M22759	0.0547	0.0748	0.0647
115	BARCEL #1	0.0545	0.0717	0.0631
120	BRAND REX #1	0.0671	0.0803	0.0737
125	CHAMPLAIN #1	0.0640	0.0757	0.0698
130	DUPONT #1	0.0576	0.0741	0.0658
135	GORE #3	0.0691	0.0707	0.0699
240	FILOTEX	0.0617	0.0714	0.0665
145	TENSOLITE #3	0.0575	0.0823	0.0699
150	THERMATICS #3	0.0552	0.0742	0.0647
155	NEMA #2	0.0608	0.0753	0.0680
160	NEMA #3	0.0722	0.0830	0.0776

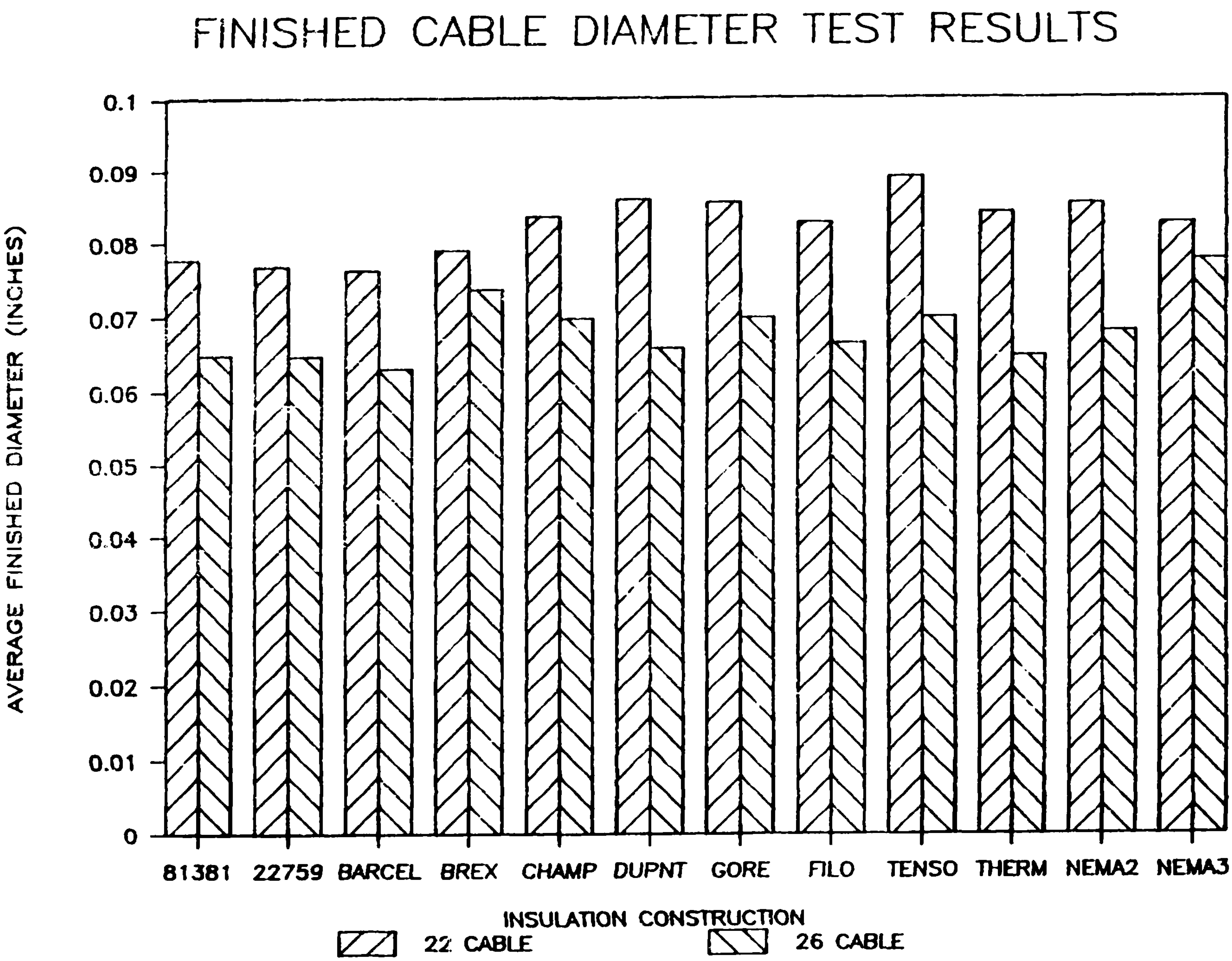
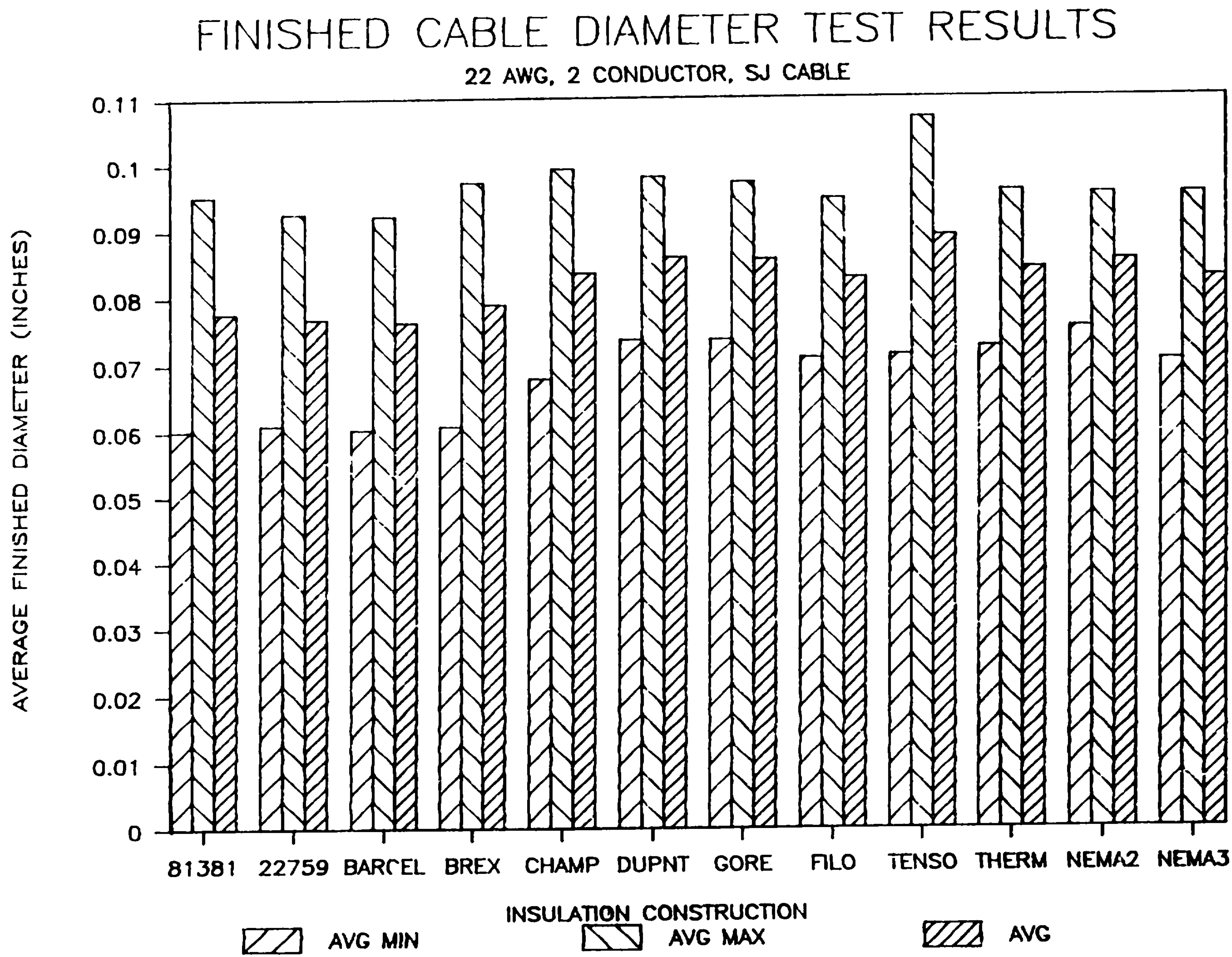


FIGURE 3.49 - FINISHED CABLE DIAMETER TEST RESULTS



<u>*FIGURE 3.50 - FINISHED CABLE DIAMETER TEST RESULTS,*</u>
<u>*22AWG, 2 CONDUCTOR, SJ CABLE*</u>

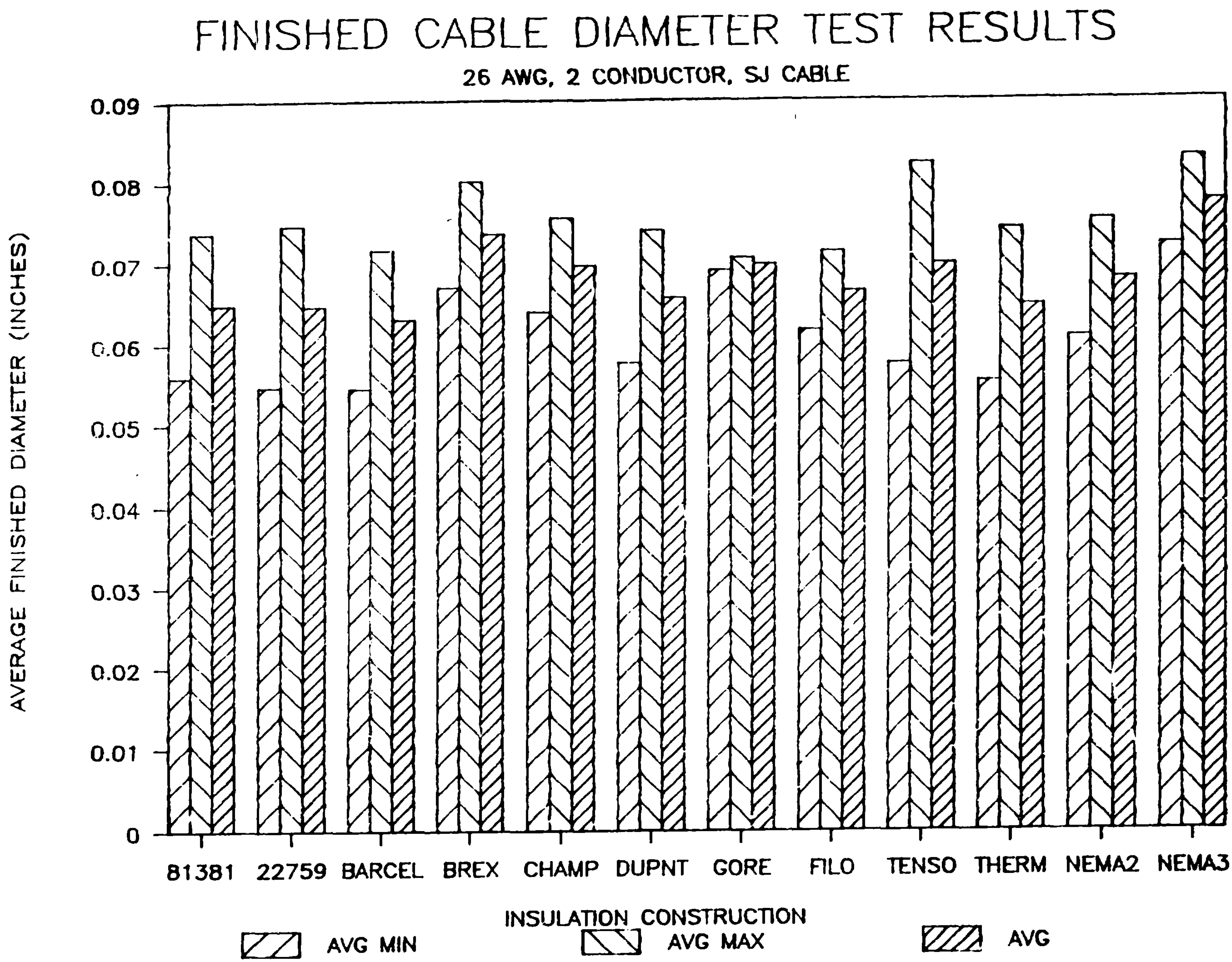


FIGURE 3.51 - FINISHED CABLE DIAMETER TEST RESULTS, 26AWG, 2 CONDUCTOR, SJ CABLE

3.9.2 FINISHED WEIGHT.

3.9.2.1 Scope: The Finished Wire and Cable Weight Test was used to evaluate the weight of a finished wire or cable sample.

3.9.2.2 Reference Procedure: The Finished Wire and Cable Weight Test was performed according to the procedure outlined in Method 902, Procedure 1, of SAE AS4373.

3.9.2.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; 26 gauge, 5.8 mil wall, hook up wire; 22 gauge, two conductor, twisted, shielded and jacketed cable; and 26 gauge, two conductor, twisted, shielded and jacketed cable. One specimen of each sample was accurately cut to a length of 10 feet ±0.0625 of an inch.

3.9.2.4 Test Equipment: A Mettler PT320 Electronic Scale (MD 083790) was used to conduct the weight measurements. The scale has the ability of measuring to the nearest thousandth of a gram.

3.9.2.5 Test Procedure: The specimen was coiled into a loop and weighed using the scale to measure the finished weight of the specimen to the nearest thousandth of a gram. The weight measurement was used to calculate a

value for a 1000 foot specimen. The weights for the 10 foot specimen and the calculated value for a 1000 foot specimen were recorded.

3.9.2.6 **Test Results:** The acquired weight for the ten foot specimens and the calculated weight for the thousand foot specimens is presented in Tables 3.82 through 3.86 with a graphical representation of the data provided in Figures 3.52 through 3.53.

TABLE 3.82 - FINISHED WEIGHT TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MEASURED WEIGHT 10 FOOT SAMPLE	CALCULATED WEIGHT 1000 FOOT SAMPLE
101	M81381	13.284 grams	2.929 pounds
106	M22759	14.073 grams	3.103 pounds
111	BARCEL #1	13.812 grams	3.045 pounds
116	BRAND REX #1	13.213 grams	2.913 pounds
121	CHAMPLAIN #1	14.205 grams	3.132 pounds
126	DUPONT #1	13.384 grams	2.951 pounds
131	GORE #3	15.501 grams	3.417 pounds
136	FILOTEX	13.302 grams	2.933 pounds
141	TENSOLITE #3	14.736 grams	3.249 pounds
146	THERMATICS #3	14.015 grams	3.090 pounds
151	NEMA #2	14.353 grams	3.164 pounds
156	NEMA #3	13.499 grams	2.976 pounds

TABLE 3.83 - FINISHED WEIGHT TEST RESULTS ON
22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MEASURED WEIGHT 10 FOOT SAMPLE	CALCULATED WEIGHT 1000 FOOT SAMPLE
102	M81381	12.202 grams	2.690 pounds
107	M22759	12.283 grams	2.708 pounds
112	BARCEL #1	12.949 grams	2.855 pounds
117	BRAND REX #1	11.843 grams	2.611 pounds
122	CHAMPLAIN #1	12.515 grams	2.759 pounds
127	DUPONT #1	12.406 grams	2.735 pounds
132	GORE #3	13.559 grams	2.989 pounds
137	FILOTEX	11.670 grams	2.573 pounds
142	TENSOLITE #3	13.698 grams	3.020 pounds
147	THERMATICS #3	12.773 grams	2.816 pounds
152	NEMA #2	13.031 grams	2.873 pounds
157	NEMA #3	12.023 grams	2.651 pounds

TABLE 3.84 - FINISHED WEIGHT TEST RESULTS ON
26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MEASURED WEIGHT 10 FOOT SAMPLE	CALCULATED WEIGHT 1000 FOOT SAMPLE
103	M81381	5.454 grams	1.202 pounds
108	M22759	5.701 grams	1.257 pounds
113	BARCEL #1	6.305 grams	1.390 pounds
118	BRAND REX #1	6.239 grams	1.376 pounds
123	CHAMPLAIN #1	6.503 grams	1.434 pounds
128	DUPONT #1	5.611 grams	1.237 pounds
133	GORE #3	6.104 grams	1.354 pounds
138	FILOTEX	5.748 grams	1.267 pounds
143	TENSOLITE #3	7.035 grams	1.551 pounds
148	THERMATICS #3	6.043 grams	1.332 pounds
153	NEMA #2	7.046 grams	1.553 pounds
158	NEMA #3	5.975 grams	1.317 pounds

TABLE 3.85 - FINISHED WEIGHT TEST RESULTS ON
22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	MEASURED WEIGHT 10 FOOT SAMPLE	CALCULATED WEIGHT 1000 FOOT SAMPLE
104	M81381	35.200 grams	7.801 pounds
109	M22759	38.200 grams	8.422 pounds
114	BARCEL #1	38.201 grams	8.422 pounds
119	BRAND REX #1	38.833 grams	8.561 pounds
124	CHAMPLAIN #1	39.142 grams	8.629 pounds
129	DUPONT #1	40.547 grams	8.939 pounds
134	GORE #3	44.795 grams	9.876 pounds
239	FILOTEX	38.440 grams	8.475 pounds
144	TENSOLITE #3	45.030 grams	9.927 pounds
149	THERMATICS #3	42.372 grams	9.341 pounds
154	NEMA #2	41.713 grams	9.196 pounds
159	NEMA #3	37.811 grams	8.336 pounds

TABLE 3.86 - FINISHED WEIGHT TEST RESULTS ON
26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	MEASURED WEIGHT 10 FOOT SAMPLE	CALCULATED WEIGHT 1000 FOOT SAMPLE
105	M81381	20.970 grams	4.623 pounds
110	M22759	24.152 grams	5.325 pounds
115	BARCEL #1	23.535 grams	5.189 pounds
120	BRAND REX #1	25.743 grams	5.675 pounds
125	CHAMPLAIN #1	23.283 grams	5.133 pounds
130	DUPONT #1	22.619 grams	4.987 pounds
135	GORE #3	24.617 grams	5.427 pounds
240	FILOTEX	22.624 grams	4.988 pounds
145	TENSOLITE #3	26.172 grams	5.770 pounds
150	THERMATICS #3	23.556 grams	5.193 pounds
155	NEMA #2	25.137 grams	5.542 pounds
160	NEMA #3	25.762 grams	5.680 pounds

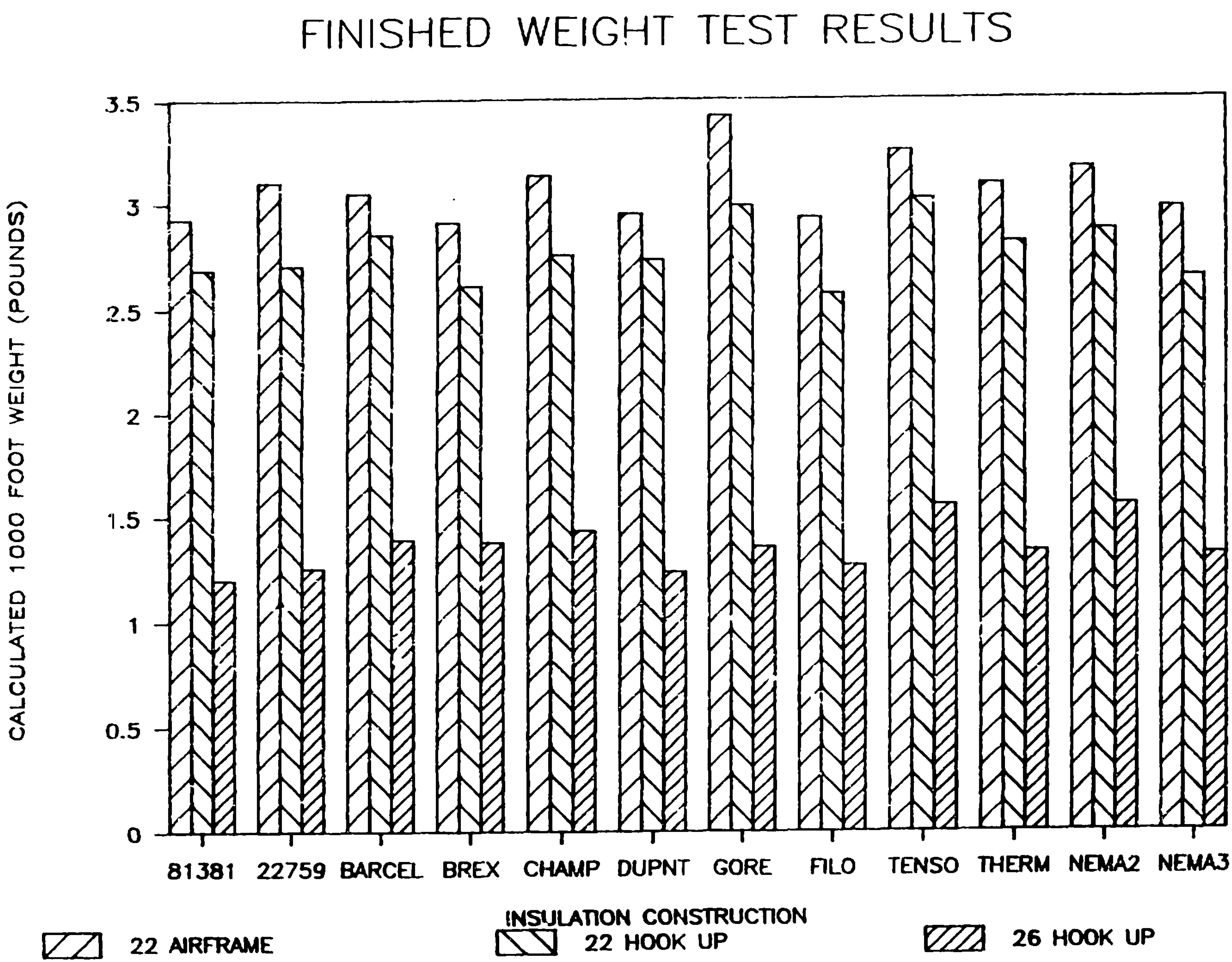


FIGURE ?.52 - FINISHED WEIGHT TEST RESULTS

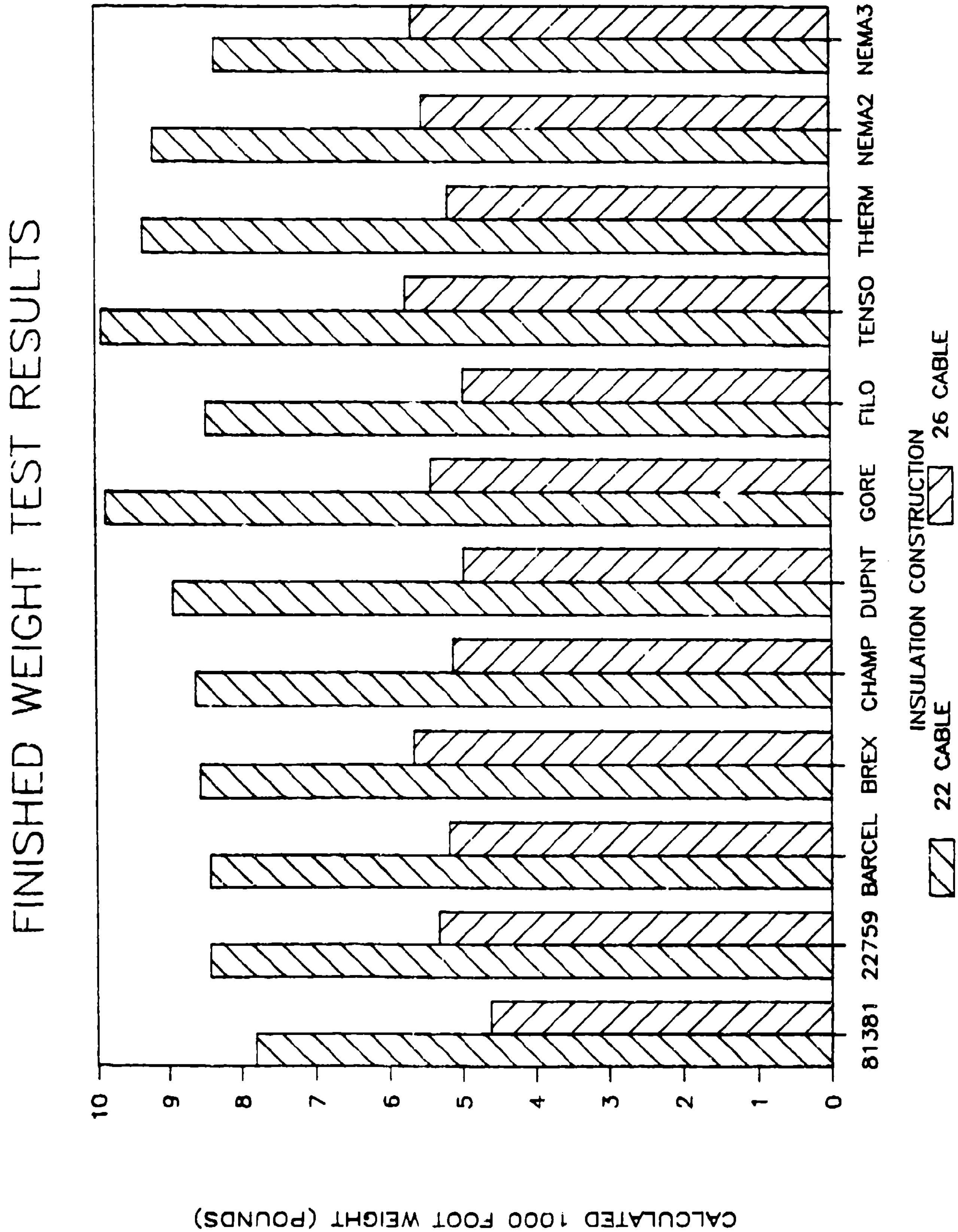


FIGURE 3.53 - FINISHED WEIGHT TEST RESULTS

4.0 SCREENING TEST STATISTICAL ANALYSIS

4.1 METHODS OF ANALYSIS. In order to discuss test results objectively, it is necessary to translate the raw data into meaningful values for comparison. A statistical analysis approach was taken to analyze the results. The analysis was performed using the standard deviation method. The best data result is scored as a 0.0. Deviation from 0.0 is determined by the following equation:

$$Z_n = (\left| X_b - X_n \right|) / S$$

where: Z_n = numerical score

X_b = best test result

X_n = candidate test result

S = unbiased standard deviation

S is determined by :

$$S = \sqrt{[\Sigma(x_n - x)^2]} / (n - 1)$$

where: x = average candidate test result

n = number of candidates

4.2 SUMMARIES OF STATISTICAL DATA. The statistical data is presented in tables 4.1 through 4.6. The tables are arranged so that the best performer, with the lowest statistical value, appears at the top of the table. All other candidates are arranged in descending order, so that the worst performer appears at the bottom of the table.

4.2.1 UNWEIGHTED SCREENING SUMMARY OF STATISTICAL RESULTS. A summary of the unweighted screening test results is shown in Table 4.1. The statistical value of all individual test performances are shown in the columns beneath the respective test name. The far right column shows the overall average statistical score for each candidate. The average score was obtained by adding all of the individual test statistical scores and dividing by the total number of tests. Where multiple gauges and/or wall thicknesses were tested, 22 gauge airframe, 22 gauge hook up wire and 26 gauge hook up wire test results were all combined to give a single test score for each construction. The shielded and jacketed statistical results have not been averaged into the screening summary statistical results because the jackets were not specified for the test program. We chose not to include jacket performance statistics in the summary of statistical results. As noted above, the lowest score indicates the highest performance. Filotex is the top performer and Brand Rex is the lowest performer.

4.2.2 WEIGHTED SCREENING SUMMARY OF STATISTICAL RESULTS. Each individual test was assigned a weight factor prior to the beginning of the test program. Weight factors were used to put more emphasis on tests which reflect critical performance issues and put less emphasis on tests reflecting less critical performance issues. The

criteria used to determine weight factors is shown below:

Failure Factors	LOW	MODERATE	HIGH
Probability of Occurrence	1	2	3
Frequency of Occurrence	1	2	3
Seriousness of Failure	1	3	5

A risk value was chosen for each of the three failure factors based upon a low, moderate, or high risk. The three risk factors were then added together and divide by two. The result is the weight factor assigned to the test. The division number is set as two rather than three because it was assumed that the sum of the probability of occurrence and frequency of occurrence is approximately equal to the seriousness of the failure. This allows for a maximum weight factor of 5.5.

Engineering representatives from MCAIR, Grumman, and Lockheed, Rye Canyon, used the formula to determine weight factors for each test. The three results were averaged to provide a single weight factor for each individual test. The determined weight factors are shown beneath each test heading in the weighted tables (4.2, 4.3, 4.4, 4.5, and 4.6).

The Weighted Screening Summary of Statistical Results is shown in Table 4.2. The average score is determined by adding all of the individual statistical test scores and dividing by the sum of the weights given to the tests. The Weighted Screening Summary of Statistical

Results was used to determine the down selection from 10 to 4 final candidates. The top two constructions in the Weighted Summary match those in the Unweighted Summary. The third and fourth constructions are reversed in order. The fifth and sixth constructions match, and the seventh and eighth, ninth and tenth, and eleventh and twelfth place pairs of constructions are all reversed. (Note that horizontal lines are used to break the constructions up into four sets of three constructions.) However, the order varies slightly within the sets.

The four candidates selected to continue in the test program were chosen based upon their statistical standing, the ability to be produced by more than a single source, and construction variation within the test group. The four candidates selected to continue in the program were:

Filotex
Thermatics
NEMA #3
Tensolite

Filotex, Thermatics, and NEMA #3 were selected as the first, second, and third place candidates respectively. Gore was ranked in fourth place among the candidates, but was not selected to continue in the test program due to its single source availability. Tensolite, the next candidate, was chosen as the fourth and final candidate to continue in the Full Performance Tests.

4.2.3 22 GAUGE AIRFRAME WIRE SCREENING SUMMARY. Statistical results for the tests run on 22 gauge airframe wire are shown in Table 4.3. Some variation in ranking was noted between the overall weighted summary and the 22 gauge airframe summary. Barcel moved from eighth place to third place, and Tensolite dropped from sixth place to ninth place. All other candidates did not vary more than one or two positions in the statistical rankings.

4.2.4 22 GAUGE HOOK UP WIRE SCREENING SUMMARY. Statistical results for the tests run on 22 gauge hook up wire are shown in Table 4.4. A little more variation in test ranking is shown between the 22 gauge hook up summary and the overall weighted summary. Filotex remained in first place.

4.2.5 26 GAUGE HOOK UP WIRE SCREENING SUMMARY. Statistical results for the tests run on 26 gauge hook up wire are shown in Table 4.5. Brand Rex showed the greatest change between the overall weighted summary and the 26 gauge hook up summary by jumping from eleventh place to sixth place. All other candidates showed little variation in ranking.

4.2.6 SHIELDED AND JACKETED CABLE SCREENING SUMMARY.

Statistical results for the tests run on 22 gauge and 26 gauge, two conductor shielded and jacketed cable are shown in Table 4.6. These results are presented separately from the overall weighted summary. No test results are presented for the Filotex construction because shielded and jacketed samples were not received in time for the Screening Tests.

TABLE 4.1 - SCREENING SUMMARY - UNWEIGHTED

INSULATION CONSTRUCTION	FINISHED DIAMETER	WIRE WEIGHT	WORKMAN-SHIP	STIFFNESS AND SPRINGBACK	DRY ARC RESIST	FLAMMA-BILITY	TOXICITY INDEX	FLUID IMMERSION	ABRA-SION	DYNAMIC CUT THROUGH	FLEX LIFE	NOTCH PROPA-GATION	VOLTAGE WITHSTAND DWV	INSULATION RESISTANCE	EXAMINE PRODUCT		AVERAGE SCORE X10
Filotex	0.16	0.23	0	1.59	0.93	0.09	0.25	0.23	0.67	2.45	2.37	0	0	0	0.25		6.15
Thermatics	0.04	1.34	0.66	1.85	0.89	0.20	0.45	0.10	0.98	1.94	1.84	0	0	0	0.53		7.16
Gore	0.18	2.53	0	0.30	0.84	0.65	1.01	0.32	2.25	2.86	0.64	0	0	0	1.28		8.57
NEMA #3	0	0.64	1.18	1.84	0.35	0.43	0.80	0.07	2.86	1.57	1.26	0	0	0	2.31		8.89
M81381	0.03	0.31	1.10	3.60	2.76	0.04	1.80	0.16	1.98	0	0.32	0	0	0	1.82		9.29
Tensolite	0.07	2.81	1.35	1.78	0.01	0.07	1.41	0.13	2.34	1.60	2.19	0	0	0	0.77		9.62
Barcel	0	1.55	0.34	2.02	0.98	0.15	1.91	0.09	2.31	2.24	1.60	0	0	0	1.53		9.78
Champlain	0	1.60	0	2.09	1.11	0.84	0.79	0.16	2.80	1.65	1.63	0	0	0	2.06		9.82
M22759	0	0.90	1.18	0.90	0.85	1.28	0.61	0.05	2.79	2.88	2.56	1.30	0	0	1.03		10.89
NEMA #2	0.02	2.29	0	2.42	0.59	0.64	2.08	0.16	1.78	1.66	2.12	0	0	0	3.06		11.21
DuPont	0	0.57	0.42	2.50	0.77	0.46	0.19	0.13	3.06	2.83	2.99	2.79	1.46	0	2.32		13.66
Brand Rex	0	0.60	2.11	2.10	1.31	0.75	0.90	1.63	2.99	1.52	2.04	1.07	0.77	1.15	2.09		14.02

007-354.09

TABLE 4.2 - SCREENING SUMMARY - WEIGHTED

INSULATION CONSTRUCTION	FINISHED DIAMETER	WIRE WEIGHT	WORKMAN-SHIP	STIFFNESS AND SPRINGBACK	DRY ARC RESIST	FLAMMA-BILITY	TOXICITY INDEX	FLUID IMMERSION	ABRA-SION	DYNAMIC CUT THROUGH	FLEX LIFE	NOTCH PROPA-GATION	VOLTAGE WITHSTAND DWV	INSULATION RESISTANCE	EXAMINE PRODUCT		AVERAGE SCORE X10
Weight Factor	4.2	4.2	3.0	4.2	5.5	4.3	5.0	4.5	5.5	4.5	5.5	5.0	5.5	4.5	3.0		
Filotex	0.67	0.97	0	6.68	5.12	0.39	1.25	1.04	3.68	11.02	13.04	0	0	0	0.75		6.52
Thermatics	0.17	5.64	2.03	7.77	4.90	0.86	2.23	0.45	5.39	8.28	10.17	0	0	0	1.59		7.23
NEMA #3	0	2.77	3.54	7.73	1.92	1.87	4.00	0.32	15.71	7.06	6.93	0	0	0	6.93		8.59
Gore	0.76	10.64	0	1.26	4.62	2.80	5.03	1.44	15.13	12.87	3.52	0	0	0	3.84		9.05
M81381	0.17	1.32	3.29	15.12	15.18	0.17	9.00	0.72	10.86	0	1.76	0	0	0	5.46		9.22
Tensolite	0.08	11.81	4.06	7.48	0.06	0.09	7.03	0.58	12.88	7.20	12.04	0	0	0	2.31		9.59
Champlain	0	6.71	0	8.78	6.10	3.63	3.95	0.72	15.40	7.42	8.96	0	0	0	6.18		9.92
Barcel	0	6.31	1.02	8.48	5.39	0.65	9.55	0.40	12.70	10.08	8.80	0	0	0	4.59		9.94
NEMA #2	0.08	9.60	0	10.16	3.24	2.76	10.40	0.72	9.76	7.47	11.66	0	0	0	9.18		10.97
M22759	0	3.76	3.54	3.78	4.68	5.49	3.03	0.22	15.35	12.96	14.08	6.50	0	0	3.09		11.18
Brand Rex	0	2.52	6.34	8.82	[illegible].20	3.21	4.50	7.34	16.44	6.84	11.22	5.35	4.24	5.18	6.27		13.96
DuPont	0	2.39	1.26	10.50	4.24	1.95	0.95	0.58	16.86	12.94	16.44	13.95	8.03	0	6.96		14.19

SUM WEIGHTS = 68.4

AVG WEIGHT = 4.56

007-354.09

TABLE 4.3 - 22 AWG AIRFRAME WIRE SCREENING SUMMARY - WEIGHTED

INSULATION CONSTRUCTION	FINISHED DIAMETER	WIRE WEIGHT	WORKMAN-SHIP	STIFFNESS AND SPRINGBACK	FLAMMA-BILITY	TOXICITY INDEX	ABRA-SION	DYNAMIC CUT THROUGH	FLEX LIFE	NOTCH PROPA-GATION	VOLTAGE WITHSTAND DWV	INSULATION RESISTANCE	EXAMINE PRODUCT		AVERAGE SCORE X10
Weight Factor	. 2	4.2	3.0	4.2	4.3	5.00	5.5	4.5	5.5	5.0	5.5	4.5	3.0		
Thermatics	0	4.91	0	8.32	0.17	0.60	4.56	8.42	9.68	0	0	0	2.37		6.68
Filotex	0	0.54	0	6.82	0.34	1.70	4.62	12.74	13.53	0	0	0	0		6.90
Barcel	0	3.65	3.06	7.94	0	2.95	12.65	10.76	5.50	0	0	0	2.31		8.36
M81381	0	0.46	0	17.18	0.34	16.15	10.07	0	0.50	0	0	0	6.90		8.84
NEMA #3	0	1.76	3.06	7.39	2.06	0	15.40	6.12	9.74	0	0	0	6.90		8.98
Gore	0	13.94	0	0.88	2.24	3.25	15.90	13.86	0	0	0	0	6.90		9.75
Champlain	0	6.05	0	7.96	2.06	3.10	15.62	6.48	12.04	0	0	0	6.90		10.31
NEMA #2	0	6.93	0	7.62	2.24	8.55	10.45	8.24	10.01	0	0	0	9.21		10.83
Tensolite	0	9.28	6.09	5.42	0.17	12.95	13.53	7.56	13.07	0	0	0	2.37		12.06
Brand Rex	0	0	9.15	7.52	2.84	4.80	16.28	9.27	13.75	0	0	0	6.90		12.07
M22759	0	5.25	3.06	5.08	7.61	5.10	14.80	13.64	14.90	2.80	0	0	4.62		13.16
DuPont	0	1.05	0	9.45	2.24	1.90	16.06	13.77	16.94	16.75	7.76	0	9.21		16.69

Sum Weight = 58.4

TABLE 4.4 : 22 AWG HOOK UP WIRE SCREENING SUMMARY : WEIGHTED

INSULATION CONSTRUCTION	FINISHED DIAMETER	WIRE WEIGHT	WORKMAN-SHIP	STIFFNESS AND SPRINGBACK	DRY ARC RESIST DWV	FLAMMA-BILITY	TOXICITY INDEX	FLUID IMMER-SION	ABRA-SION	DYNAMIC CUT THROUGH	FLEX LIFE	NOTCH PROPA-GATION	VOLTAGE WITHSTAND DWV	INSULATION RESISTANCE	EXAMINE PRODUCT	AVERAGE SCORE X10
Weight Factor	4.2	4.2	3.0	4.2	5.5	4.3	5.0	4.5	5.5	4.5	5.5	5.0	5.5	4.5	3.0	
Filotex	0	0	0	8.27	6.60	0.43	0.80	1.04	2.75	10.12	12.76	0	0	0	0	6.25
Gore	0	12.35	0	2.90	5.88	3.35	6.80	1.44	14.36	9.54	0	0	0	0	2.43	8.63
M81381	0	3.49	6.09	14.82	14.68	0	1.85	0.72	11.66	0	0.28	0	0	0	7.26	8.90
Tensolite	0	13.27	6.09	8.11	0	0	1.10	0.58	12.26	3.87	13.14	0	0	0	2.43	8.90
Thermatics	0	7.22	6.09	8.88	6.60	1.55	3.85	0.45	6.22	6.70	12.32	0	0	0	2.43	9.11
NEMA #3	0	2.31	0	9.20	5.06	1.68	8.00	0.32	16.00	3.82	11.11	0	0	0	7.26	9.47
M22759	0	3.49	0	3.04	5.88	3.35	0.95	0.22	15.90	11.70	14.46	5.00	0	0	2.43	9.78
NEMA #2	0	8.90	0	11.24	2.16	3.27	12.25	0.72	9.08	4.59	13.58	0	0	0	7.25	10.71
Champlain	0	5.50	0	9.76	10.67	5.20	4.80	0.72	15.18	4.32	10.34	0	0	0	7.26	10.78
Barcel	0	8.36	0	8.69	9.29	1.29	16.15	0.40	12.76	8.73	11.60	0	0	0	4.83	12.00
DuPont	0	4.83	0	11.53	4.73	1.68	0	0.58	17.66	12.82	17.98	12.90	10.72	0	7.26	15.01
Brand Rex	0	1.13	6.09	7.84	8.30	3.57	4.20	7.34	16.61	4.14	15.02	10.70	7.15	15.57	9.69	17.23

SUM WEIGHT = 68.4

TABLE 4.5 - 26 AWG HOOK UP WIRE SCREENING SUMMARY - WEIGHTED

INSULATION CONSTRUCTION	FINISHED DIAMETER	WIRE WEIGHT	WORKMAN-SHIP	STIFFNESS AND SPRINGBACK	DRY ARC RESIST	DYNAMIC CUT THROUGH	FLEX LIFE	NOTCH PROPA-GATION	VOLTAGE WITHSTAND DWV	INSULATION RESISTANCE	EXAMINE PRODUCT		AVERAGE SCORE X10
Weight Factor	4.2	4.2	3.0	4.2	5.5	4.5	5.5	5.0	5.5	4.5	3.0		
Thermatics	0.46	4.79	0	6.07	5.72	9.72	8.42	0	0	0	0		7.16
NEMA #3	0	4.24	7.56	6.66	0	11.25	0	0	0	0	6.63		7.40
M81381	0.46	0	3.78	13.25	15.29	0	4.56	0	0	0	2.22		8.06
Filotex	2.06	2.39	0	4.87	5.72	10.26	12.87	0	0	0	2.22		8.23
Gore	2.27	5.63	0	0	5.72	15.21	10.50	0	0	0	2.22		8.46
Brand Rex	0	6.43	3.78	11.10	2.86	7.06	4.95	0	5.56	0	2.22		8.95
Tensolite	0.21	12.89	0	8.90	0	10.17	9.84	0	0	0	2.22		9.01
Champlain	0	8.57	0	8.61	6.82	11.52	4.56	0	0	0	4.41		9.06
Barcel	0	6.93	0	8.84	5.72	11.79	9.30	0	0	0	6.63		10.02
M22759	0	2.02	7.56	3.26	5.72	13.59	12.92	13.30	0	0	2.22		12.34
NEMA #2	0.21	12.98	0	11.70	5.72	9.58	11.33	0	0	0	11.07		12.75-
DuPont	0	1.30	3.78	10.58	5.72	11.56	14.46	13.30	5.56	0	4.41		14.40

SUM WEIGHT = 49.1

TABLE 4.6 - SJ CABLE SCREENING SUMMARY - WEIGHTED

INSULATION CONSTRUCTION	WIRE WEIGHT	FINISHED DIAMETER	WORKMAN-SHIP	FLAMMABILITY	TOXICITY INDEX	AVERAGE SCORE X10
Weight Factor	4.2	4.2	3.0	4.3	5.0	
M81381	0	0	0.42	0.73	1.15	1.11
DuPont	5.80	0	2.22	0.90	0	4.31
Champlain	5.71	0	0	2.58	0.70	4.34
Barcel	5.42	0	2.64	0	5.70	6.65
M22759	6.22	0	2.22	4.47	4.15	8.24
Thermatics	8.32	0	0	0.34	8.85	8.45
Brand Rex	8.82	0	2.64	4.94	2.25	9.01
NEMA #3	8.15	0	0	5.33	6.55	9.68
Tensolite	13.69	0	4.26	0.56	6.75	12.20
Gore	11.00	0	0.42	1.29	15.20	13.48
NEMA #2	10.00	0	9.36	1.80	13.15	16.57

Filotex submitted no SJ Cable for Screening Tests

SUM WEIGHT = 20.7

5.0 FULL PERFORMANCE TEST PROCEDURES AND RESULTS

The screening tests resulted in the selection of four final candidates and more comprehensive full performance tests were conducted on four final candidates and two baseline. The full performance candidates were chosen by statistical analysis of the data acquired from the screening tests. Statistical analysis provided an objective evaluation of the insulation candidates performance.

The full performance sequence of testing consisted of tests that complemented the screening tests to provide a thorough analysis of the candidates performance. The full performance section consisted of twenty eight tests that are presented in Table 5.1.

TABLE 5.1 - FULL PERFORMANCE TEST SUMMARY

SAE METHOD	TEST	22 AWG AIRFRAME WIRE	20 AWG HOOKUP WIRE	26 AWG HOOKUP WIRE	22 AWG CABLE	26 AWG CABLE	12 AND 16 AWG WIRE
(1)	JACKET WALL THICKNESS				X	X	
(2)	BSI DRY ARC RESISTANCE AND FAULT PROPAGATION						X
501	DIELECTRIC CONSTANT	X	X	X			
502	CORONA INCEPTION AND EXTINCTION	X	X	X			
506	SURFACE RESISTANCE	X	X				
507	TIME/CURRENT TO SMOKE	X	X	X	X	X	
509	WET ARC TRACKING	X	X				
511	WIRE FUSING TIME	X	X	X			
602	FORCED HYDROLYSIS		X	X			
603	HUMIDITY RESISTANCE	X	X	X			
604	WEIGHT LOSS UNDER VACUUM AND TEMPERATURE	X			X		
606	WEATHERING RESISTANCE	X	X	X	X		
607	WICKING	X	X	X			
701	ABRASION	X	X				
703	COLD BEND	X	X		X		
(3)	CRUSH RESISTANCE	X	X	X			
703	DYNAMIC CUT THROUGH	X	X	X			
704	FLEX LIFE	X	X	X	X	X	
705	INSULATION IMPACT RESISTANCE	X	X	X			
706	INSULATION TENSILE STRENGTH AND ELONGATION	X	X				
707	NOTCH PROPAGATION	X	X	X			
(4)	WIRE TO WIRE RUB TEST						
(5)	AGING STABILITY				X	X	
803	SMOKE QUANTITY	X	X	X	X	X	
804	THERMAL INDEX	X	X				
805	THERMAL SHOCK	X	X	X	X	X	
807	PROPERTY RETENTION AFTER THERMAL AGING	X	X	X			
712	WIRE SURFACE MARKABILITY	X	X	X			

(1) - Performed according to Federal Test Standard 228, Method 1018
(2) - Performed according to British Standard Institute 90/76828 and 90/80606
(3) - Performed according to ASTM D3032, Section 20
(4) - Performed according to a procedure developed at DAC
(5) - Performed according to MIL-C27500G, Paragraph 4.5.10

5.1 ASSEMBLY, HANDLING, AND REPAIR TESTS

5.1.1 JACKET WALL THICKNESS.

5.1.1.1 Scope: The Jacket Wall Thickness Test was used to determine the wall thickness of a finished cable sample by use of an optical measuring method.

5.1.1.2 Reference Procedure: The Jacket Wall Thickness determination was conducted according to Method 1018 of Federal Test Standard 228, because Method 101 of SAE AS4373 was a procedure designed for wire specimens.

5.1.1.3 Specimens: Specimens were constructed from 22 and 26 gauge, two conductor, twisted, shielded and jacketed (SJ) cable samples. Six unconditioned specimens of each sample were cut to a length of one half inch using a single edged razor blade to minimize deformation of the specimen's jacket. The specimens utilized the Finished Cable Diameter specimens for this test. Three specimens were cut from each sample that corresponded to each end of the spool. The specimens were placed on a 10 x 4 x 0.75 inch steel jig plate and a single ended razor blade was hit with a hammer to cut the specimen flush. If the specimen was excessively deformed, another specimen was constructed.

5.1.1.4 Test Equipment: A Nikon measuring microscope (MD 115812) with a calibrated position sensor was used to acquire the wall measurements to a minimum accuracy of at least 0.0002 inches.

5.1.1.5 Test Procedure: The specimen was mounted in an upright position beneath the microscope lens and examined under a 50 times power setting to determine the finished jacket wall thickness. The jacket wall thickness was measured in six different areas that were not deformed by the cutting tool to determine the maximum and minimum wall thickness of each specimen. These values were recorded and the average maximum and average minimum wall thickness was determined from those measurements. The 50% overlap points of the tape jackets were included in the measurements.

The jacket wall thickness values were recorded and the average maximum wall thickness and the average minimum wall thickness were calculated.

5.1.1.6 Test Results: The average minimum and maximum wall thicknesses are presented in Tables 5.2 through 5.3 with a graphical representation of the data presented in Figure 5.1.

TABLE 5.2 - JACKET WALL THICKNESS TEST RESULTS ON
22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE MINIMUM WALL THICKNESS (MILS)	AVERAGE MAXIMUM WALL THICKNESS (MILS)
104	M81381	2.73	4.20
109	M22759	3.20	6.20
239	FILOTEX	4.50	9.20
144	TENSOLITE #3	3.33	7.20
149	THERMATICS #3	4.83	7.10
159	NEMA #3	4.37	7.00

TABLE 5.3 - JACKET WALL THICKNESS TEST RESULTS ON
26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE MINIMUM WALL THICKNESS (MILS)	AVERAGE MAXIMUM WALL THICKNESS (MILS)
105	M81381	3.70	6.00
110	M22759	3.42	6.13
240	FILOTEX	3.73	7.57
145	TENSOLITE #3	3.65	6.57
150	THERMATICS #3	4.63	7.57
160	NEMA #3	4.53	7.03

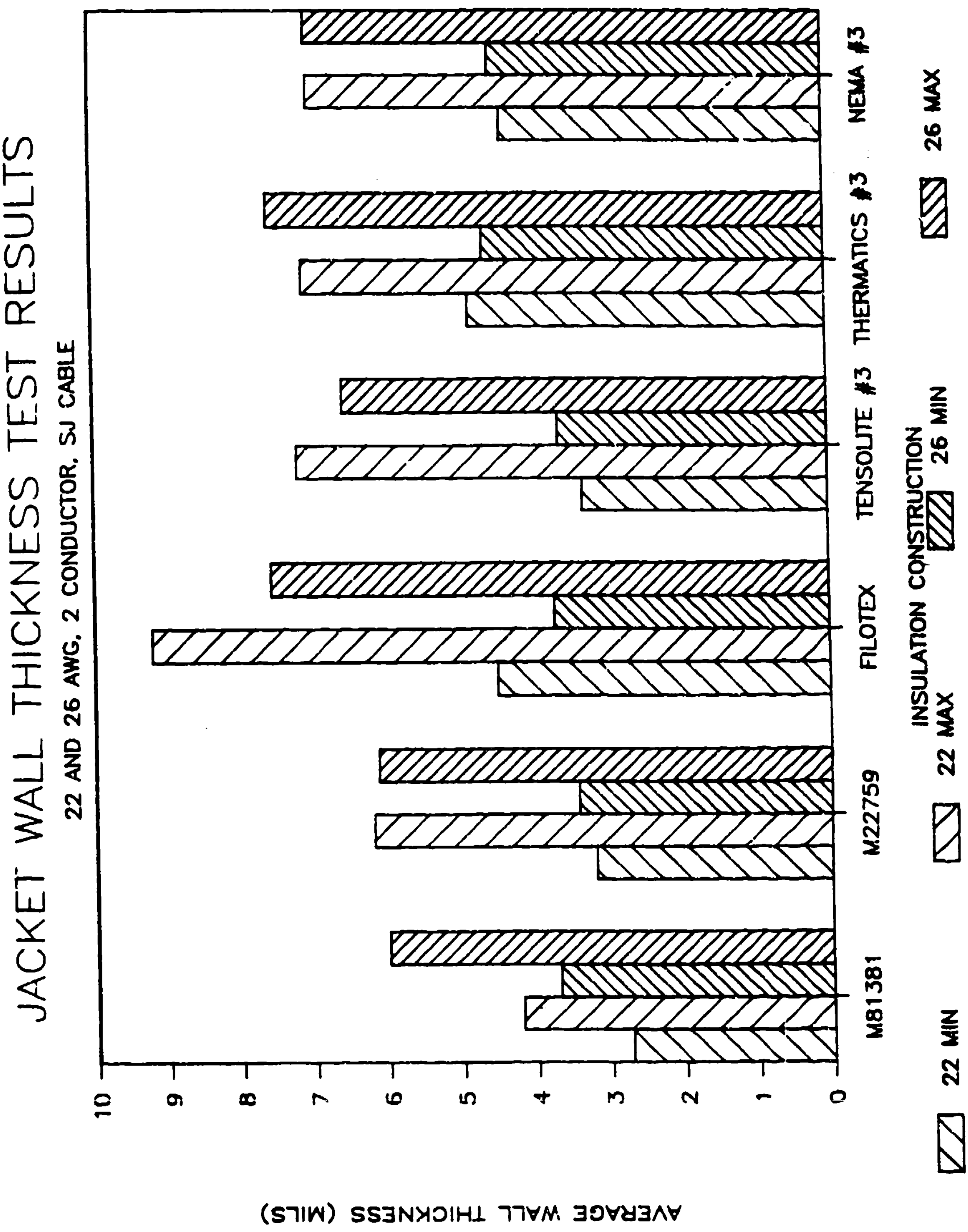


FIGURE 5.1 - JACKET WALL THICKNESS TEST RESULTS

5.2 COMBAT DAMAGE TESTS

5.2.1 BSI DRY ARC RESISTANCE AND FAULT PROPAGATION TEST.

5.2.1.1 Scope: The Dry Arc Propagation Test patterned after the British Standards Institute procedure endeavors to simulate representative aircraft harness damage to initiate an arc and identify corollary harness damage resulting from the creation of the arc.

5.2.1.2 Reference Procedure: The Dry Arc Resistance and Fault Propagation Test was conducted according to the British Standards Institute's (BSI) test documents BSI 90/76828 and 90/80606. The test was modified to include a three phase, 115 volt, 400 Hertz, F-15E aircraft generator to supply ac power and two paralleled 28 volt dc Transformer Rectifier Units to supply dc power. The frequency of oscillation of the arc initiation blade was changed to 10 Hertz from the 30 Hertz stated in the BSI document. No additional, non-inductive resistance was introduced into the test setup, since an actual F-15 electrical system was used to supply power for the test.

5.2.1.3 Specimens: Three, seven wire harnesses were fabricated for each of the five thermally aged insulation samples tested, for a total of 15 harness test specimens (M81381 insulation was not tested because it has a known

propensity for arc propagation). Each harness consisted of four 12 gauge, 8.6 mil wall, airframe wires and three 16 gauge, 5.8 mil wall, hook up wires that had been thermally aged in a forced draft air oven at 210°C (410°F) for 504 hours.

The harnesses were constructed by cutting the seven wires to a length of approximately 28 inches. One 12 gauge wire (Wire 1) and one 16 gauge wire (Wire 2) had a 0.04 inch wide segment of insulation circumferentially notched by using a Reon coaxial cable stripper. The notched segment of insulation was removed from the center of the wires without damaging the conductors. The seven wires were then placed in the appropriate locations of two 19 socket Burndy connectors (P/N G0A16-19SNE), which were held firmly in two vises 24 inches apart. Figure 5.2 identifies the position of all wires within the harness. The wires also passed through a third connector, which had the grommet removed. This connector was allowed to slide freely along the length of the harness between the two fixed connectors. This connector was used to assure proper parallel orientation of the wires when securing the fiberglass lacing chords to the harness. The two notched specimens were adjusted to position the notches parallel and adjacent to one another. The fiberglass lacing chord (MIL-43435B, type IV) was first placed 10 millimeters from each side of the notches on wires 1 and 2. The remaining fiberglass ties were spaced 20

millimeters apart for the remainder of the harness.

The wires were tagged and identified according to Table 5.4 and Figure 5.2. The specimen was removed from the fixture and cut to achieve a finished harness length of 24±1 inches. The wires on one end of the test harness had a quarter inch of insulation removed and were terminated with ring terminals. The opposite end of the specimen had each individual wire enclosed in heat shrink sleeving to prevent any inadvertent shorting at the end of the harness.

TABLE 5.4 - WIRE: IDENTIFICATION, GAUGE, AND POWER SOURCE

WIRE NO.	WIRE GAUGE	POWER SOURCE	NOTCHED
1	12 gauge	Phase A	Yes
2	16 gauge	Phase B	Yes
3	12 gauge	+28 VDC	No
4	12 gauge	28 VDC Return	No
5	16 gauge	Phase C	No
6	12 gauge	Earth Ground	No
7	16 gauge	Neutral	No

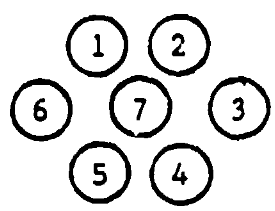


FIGURE 5.2 - WIRE POSITIONS WITHIN HARNESS

5.2.1.4 Test Equipment: Thermal circuit-breakers, MS3320, were installed on a chassis and were placed in series between the power source and the appropriate wire within the harness. The circuit breakers were included in the

test to simulate an actual aircraft system. Table 5.5 lists the circuit breaker current rating for the appropriate wire gauge. The circuit breakers were tested prior to each Fault Propagation Test to verify their proper operation. They were tested using a dc power supply at a 200% overload current to verify trip within 1.5 to 40 seconds.

TABLE 5.5 - THERMAL CIRCUIT-BREAKERS

WIRE NO.	POWER SOURCE	CURRENT RATING
1	Phase A	30 Amps
2	Phase B	20 Amps
3	+28 VDC	30 Amps
5	Phase C	20 Amps

The ac power was supplied for the test by an F-15E generator. The generator was a constant speed drive system rated at 75,000 volt-amperes. The Constant Speed Drive was manufactured by Sunstrand and the Generator was manufactured by Lucas. The generating system is rated at 115 volts, three phase, 400 Hertz. The generator control unit, manufactured by Lucas, provided undervoltage and overcurrent protection by monitoring the output of a current transformer assembly. To trigger the undervoltage protection circuit, any single phase must drop to 95±5 volts for five seconds before the control unit will shut down the generator. It also monitors differential line current and will shut down the generator instantaneously if a 40±5 amp difference is

detected between any two phases. The generator was mounted to a 200 horsepower General Electric motor. The dc power was supplied by two transformer rectifier units (TRU) manufactured by Eldec. The TRU's were connected in parallel. Each TRU was rated at 28 volts dc with a current rating of 150 amps which provided a total rated dc current output of 300 amps. The test utilized a Hartman Electrical Manufacturing power contactor which was controlled by the generator control unit. The Fault Propagation Test was initiated by closing a Jack and Heintz, 115 volt, three phase, power contactor to switch the ac power and a 28 volt dc Gaurdian Electric Mfg. Co. relay to switch the dc power. Power was applied to the four harness conductors via triplet 12 gauge wires when the ac and dc power contactors were energized simultaneously.

The test setup was designed so that a vibrating aluminum blade would initiate the arc. The 1 x 0.6 x 0.125 inch blade was constructed of T6061-T6 aluminum and the blade edge was ground to a 90° edge by 24 grit sand paper.

The aluminum blade was installed in a guillotine type device which was attached to a reciprocating arm. The arm and dc drive motor were constructed to oscillate the blade and guillotine assembly at 10 Hertz. The blade was connected to the generator neutral by a using a six inch segment of the shield from ST5M1247-16-35J cable. The

amount of force applied by the blade to the wire harness was controlled by the amount of weight placed on the guillotine. The maximum blade depth was adjusted by a mechanical stop. An electromagnetic system was used to remove the blade from the harness 10 seconds after a circuit breaker tripped. The wire harness was held in place by two insulated clamps spaced four inches to either side of the damaged wires.

The test setup was designed to monitor the currents in each wire of the harness and also the current through the blade, which was connected to neutral. Weston Current Transformers, Model 327, were used to monitor the alternating currents of phase A (Wire 1), phase B (Wire 2), and phase C (Wire 5). The blade, which was connected to neutral, was also monitored via a Weston current transformer. Weston, 450 amp, 50 millivolt, shunts were used to monitor the dc currents in the +28 volt dc (Wire 3), 28 volt dc return (Wire 4), earth ground (Wire 6), and neutral (Wire 7). The differontial signals generated by the shunts were connected to the Soltec Signal Memory Recorder (SMR) through Preston Instrumentation Amplifiers. The amplifiers converted the differential output of the shunts to a single-ended output which could then be recorded by the Soltec. The data acquisition system used to record data was a Soltec Signal Memory Recorder (MD 117327). The system was configured with a sample rate of 100 microseconds with a 12.5% pre-trigger

delay. A total of 65,536 samples were acquired per channel. Tables 5.6 and 5.7 provide the data acquisition system settings and instrumentation serial numbers used for data collection

TABLE 5.6 - AC CURRENT DATA INSTRUMENTATION

PARAMETER MEASURED	SOLTEC SMR VOLTAGE RANGE	SOLTEC SMR SIGNAL OFFSET	WESTON CURRENT TRANSFORMER S/N
Phase A	0 to 5 V	50%	107803
Phase B	0 to 5 V	50%	037376
Phase C	0 to 5 V	50%	114733
Blade (Neutral)	0 to 5 V	50%	028638

TABLE 5.7 - DC CURRENT DATA INSTRUMENTATION

PARAMETER MEASURED	SOLTEC SMR VOLTAGE RANGE	SOLTEC SMR SIGNAL OFFSET	PRESTON AMPLIFIER S/N	PRESTON AMPLIFIER GAIN	PRESTON AMPLIFIER FILTER	WESTON SHUNT 450A / 50mV S/N
Ground	0 to 2.5 V	50%	071662	20	10k Hz	140731
Neutral	0 to 2.5 V	50%	071653	20	10k Hz	140730
+28 VDC	0 to 2.5 V	50%	071648	20	10k Hz	140729
28 VDC Return	0 to 2.5 V	50%	071647	20	10k Hz	160156

A Slaughter 103/105 High Voltage Leakage Tester (MD 127358) was used to conduct the Voltage Withstand Test on the wires in the harness following the Fault Propagation Test. The dielectric tester was preset to apply a 500 volt per second increase until the test voltage of 1500 volts was achieved for one minute or a failure occurred.

The tests were recorded on 0.5 inch video tape to provide a visual record of arcing, flaming of insulation, and post test damage.

Photographs of the test setup and equipment are presented in Figures 5.6 through 5.9.

5.2.1.5 Test Procedure: The blade weight was set to apply 52 grams of force on the harness and the frequency of the reciprocating blade was set at 10 Hertz. The wire harness was secured in the test setup using the two insulated harness clamps which were placed four inches on each side of the notch. The harness was positioned so that the two notched wires were on top of the harness. The aluminum blade was then brought in contact with the exposed conductors of the notched wires, Wire 1 (Phase A) and Wire 2 (Phase B). In some cases, the insulation was too thick and the blade was not sharp enough to make contact with the conductor. If this occurred, the notch in the insulation was widened by using an X-acto knife so that the aluminum blade could make contact with the conductor. In order to insure contact with the conductor, a continuity check was performed between the blade and wires 1 and 2. The harness diameter was measured and the maximum blade depth was adjusted to half of the harness diameter using the adjustable mechanical stop.

The test was initiated by bringing the F-15E generator up to speed, starting the video equipment, and supplying power to the motor driving the reciprocating blade. When the reciprocating arm acquired the speed of 10 Hertz, the ac and dc contactors were energized to apply power to the harness simultaneously. Power was maintained to the harness for 10 seconds after a circuit-breaker opened. The blade was removed from the harness, the generator was brought off line, and the dc motor was turned off. Data that was recorded by the Soltec SMR was stored on five and a quarter inch disks. The circuit breakers that tripped were recorded and visual harness damage measurements were made and recorded.

A restrike attempt was performed on the specimen 15 to 20 minutes after the initial strike. The blade was not included in the restrike attempt. Circuit breakers were reset. The restrike attempt was initiated by bringing the F-15E generator up to speed, starting the video equipment, and closing the power contactors. If current was detected, the data was stored on disk. The additional harness damage sustained as a result of the restrike was recorded along with the circuit breakers that tripped.

Photographs of the test specimens were acquired prior to the Voltage Withstand Test.

A Voltage Withstand Test was performed on the test harness after exposure to the Fault Propagation Test to identify the damage to adjacent wires which were not directly involved in the arc initiation. The harness was submerged in a 5% salt (NaCl) solution for a five minute soak without bending the test specimen. At the completion of the five minute soak, a test potential of 1500 volts at 60 Hertz was applied between each individual conductor and an electrode placed in the solution for one minute. The leakage current of the wire was recorded unless a short was detected. The results of the Voltage Withstand Test were recorded.

The video provided verification of the presence of arcing, smoke, and secondary fire (produced by burning insulation) during testing and also provided a post-test record of harness damage.

5.2.1.6 **Test Results:** Visual harness damage was recorded for physical phenomenon such as length of harness disintegrated as a result of the arc, length of insulation charring, and the amount of exposed or recessed conductor. These observations and the current duration measurements are provided in Tables 5.8 through 5.11 with graphical representation of the data presented in Figures 5.3 through 5.5. Exhibit A of Volume I of this report provides photographic documentation of the test results.

TABLE 5.8 - INITIAL POWER APPLICATION TEST RESULTS

SPOOL REF.	INSULATION CONSTRUCTION	TEST RUN	CIRCUIT BREAKER øA	CIRCUIT BREAKER øB	CIRCUIT BREAKER øC	CIRCUIT BREAKER 28 VDC	AVERAGE CURRENT DURATION (MILLISECONDS)
206	M22759	A	T	T	-	-	13.33
206	M22759	B	T	T	-	-	24.97
206	M22759	C	T	T	-	-	15.49
236	FILOTEX	A	-	T	-	-	7.45
236	FILOTEX	B	-	T	-	-	12.51
236	FILOTEX	C	T	T	-	-	13.48
241	TENSOLITE #3	A	T	T	-	-	10.91
241	TENSOLITE #3	B	T	T	-	-	14.75
241	TENSOLITE #3	C	T	T	-	-	24.13
246	THERMATICS #3	A	T	T	-	-	51.43
246	THERMATICS #3	B	T	T	-	-	13.44
246	THERMATICS #3	C	T	T	-	-	27.77
256	NEMA #3	A	T	T	-	-	>1691.67
256	NEMA #3	B	T	T	-	-	12.83
256	NEMA #3	C	T	T	-	-	5787.30

T = C/B TRIPPED   - = C/B REMAINED CLOSED

TABLE 5.9 - RESTRIKE POWER APPLICATION TEST RESULTS

SPOOL REF.	INSULATION CONSTRUCTION	TEST RUN	CIRCUIT BREAKER øA	øB	øC	28 VDC	AVERAGE CURRENT DURATION (MILLISECONDS)
206	M22759	A	-	-	-	-	0.00
206	M22759	B	-	T	-	-	13.21
206	M22759	C	-	-	-	-	0.00
236	FILOTEX	A	-	-	-	-	0.00
236	FILOTEX	B	-	-	-	-	0.00
236	FILOTEX	C	-	-	-	-	0.00
241	TENSOLITE #3	A	-	-	-	-	0.00
241	TENSOLITE #3	B	-	-	-	-	0.00
241	TENSOLITE #3	C	-	-	-	-	0.00
246	THERMATICS #3	A	-	-	-	-	0.00
246	THERMATICS #3	B	-	-	-	-	0.00
246	THERMATICS #3	C	-	-	-	-	0.00
256	NEMA #3	A	T	T	-	-	>2029.78
256	NEMA #3	B	-	-	-	-	0.00
256	NEMA #3	C	T	T	-	T	2864.73

T = C/B TRIPPED   - = C/B REMAINED CLOSED

TABLE 5.10 - HARNESS DAMAGE TEST RESULTS

SPOOL REF.	INSULATION CONSTRUCTION	TEST RUN	INITIAL AVERAGE LENGTH OF HARNESS CONSUMED (inches)	RESTRIKE ADDITIONAL AVERAGE LENGTH OF HARNESS CONSUMED (inches)	INITIAL AVERAGE LENGTH OF CHARRED INSULATION (inches)	RESTRIKE ADDITIONAL AVERAGE LENGTH OF CHARRED INSULATION (inches)	INITIAL AVERAGE LENGTH OF CARBON RESIDUE (inches)	RESTRIKE ADDITIONAL AVERAGE LENGTH OF CARBON RESIDUE (inches)	INITIAL AVERAGE LENGTH OF EXPOSED CONDUCTOR (inches)	RESTRIKE ADDITIONAL AVERAGE LENGTH OF EXPOSED CONDUCTOR (inches)
206	M22759	A	0.04	0.00	0.00	0.00	0.50	0.00	0.01	0.00
206	M22759	B	0.01	0.08	0.00	0.00	0.66	0.00	0.07	0.00
206	M22759	C	0.04	0.00	0.01	0.00	0.23	0.00	0.02	0.00
236	FILOTEX	A	0.03	0.00	0.02	0.00	0.53	0.00	0.03	0.00
236	FILOTEX	B	0.03	0.00	0.01	0.00	0.56	0.00	0.00	0.00
236	FILOTEX	C	0.03	0.00	0.01	0.00	0.60	0.00	0.01	0.00
241	TENSOLITE #3	A	0.04	0.00	0.00	0.00	0.43	0.00	0.04	0.00
241	TENSOLITE #3	B	0.03	0.00	0.01	0.00	0.46	0.00	0.02	0.00
241	TENSOLITE #3	C	0.03	0.00	0.01	0.00	0.47	0.00	0.01	0.00
246	THERMATICS #3	A	0.03	0.00	0.04	0.00	0.60	0.00	0.01	0.00
246	THERMATICS #3	B	0.03	0.00	0.07	0.00	0.36	0.00	0.01	0.00
246	THERMATICS #3	C	0.04	0.00	0.00	0.00	0.43	0.00	0.04	0.00
256	NEMA #3	A	1.74	1.19	0.30	0.00	0.57	0.73	1.71	0.77
256	NEMA #3	B	0.02	0.00	0.02	0.00	0.53	0.00	0.01	0.00
256	NEMA #3	C	3.07	1.33	0.30	0.04	0.86	0.29	1.71	0.86

TABLE 5.11 - VOLTAGE WITHSTAND TEST RESULTS

SPOOL REF.	INSULATION CONSTRUCTION	TEST RUN	CONDUCTOR NUMBER 1	2	3	4	5	6	7	SUMMARY (P / F)
206	M22759	A	F	F	F	P	P	P	F	3 / 4
206	M22759	B	F	F	F	P	P	F	F	2 / 5
206	M22759	C	F	F	F	P	P	F	F	2 / 5
236	FILOTEX	A	F	F	P	P	P	P	P	5 / 2
236	FILOTEX	B	F	F	P	P	P	P	P	5 / 2
236	FILOTEX	C	F	F	F	P	P	P	P	4 / 3
241	TENSOLITE #3	A	F	F	F	P	P	P	F	3 / 4
241	TENSOLITE #3	B	F	F	F	P	P	P	F	3 / 4
241	TENSOLITE #3	C	F	F	F	P	P	P	F	3 / 4
246	THERMATICS #3	A	F	F	F	P	P	P	F	3 / 4
246	THERMATICS #3	B	F	F	F	P	P	P	F	3 / 4
246	THERMATICS #3	C	F	F	F	P	P	P	F	3 / 4
256	NEMA #3	A	F	F	F	F	P	F	F	1 / 6
256	NEMA #3	B	F	F	F	P	P	P	F	3 / 4
256	NEMA #3	C	F	F	F	F	F	F	F	0 / 7

F = LEAKAGE CURRENT GREATER THAN 5 MILLIAMPS.
P = LEAKAGE CURRENT LESS THAN 5 MILLIAMPS.

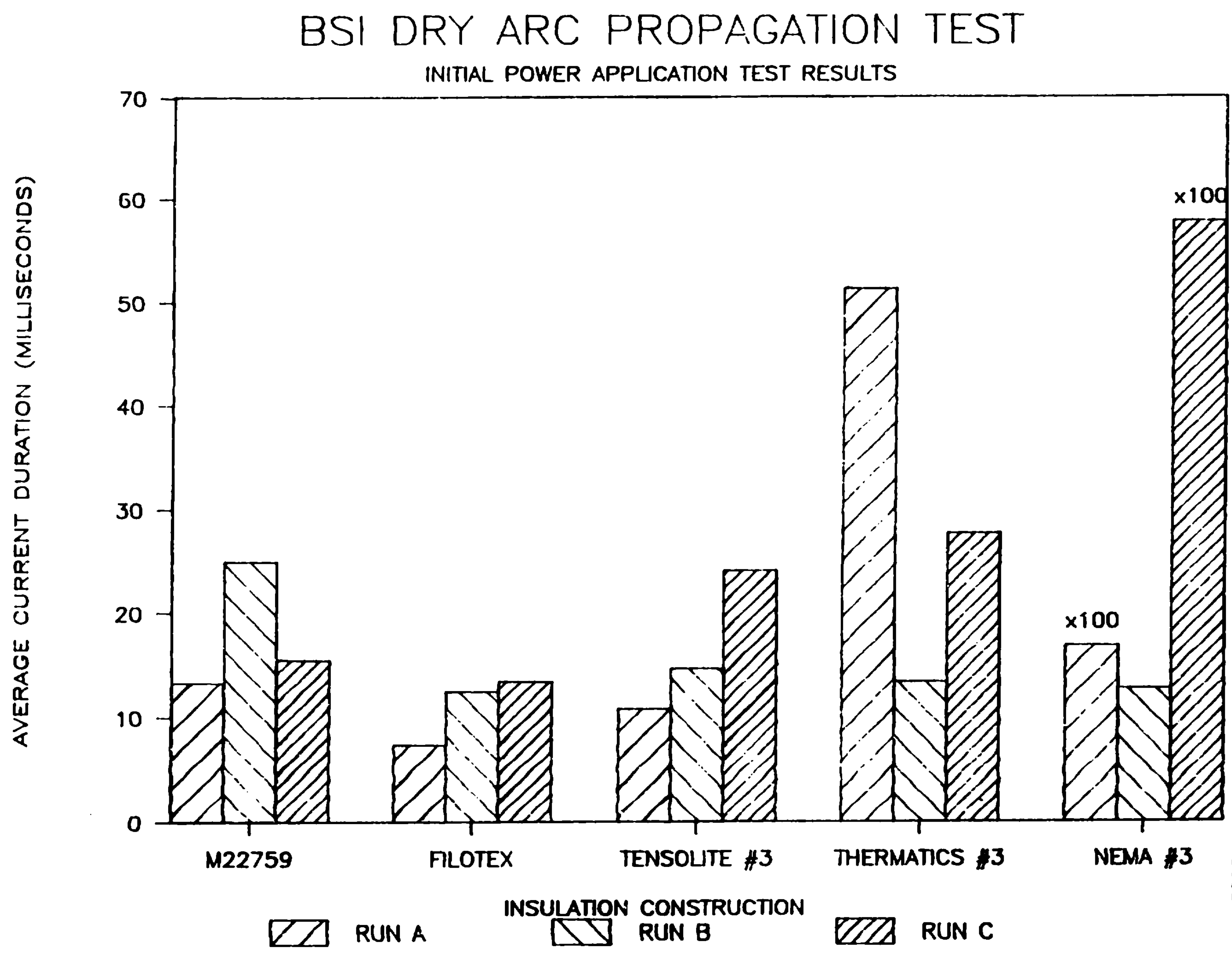


FIGURE 5.3 - BSI DRY ARC PROPAGATION TEST, INITIAL POWER APPLICATION TEST RESULTS

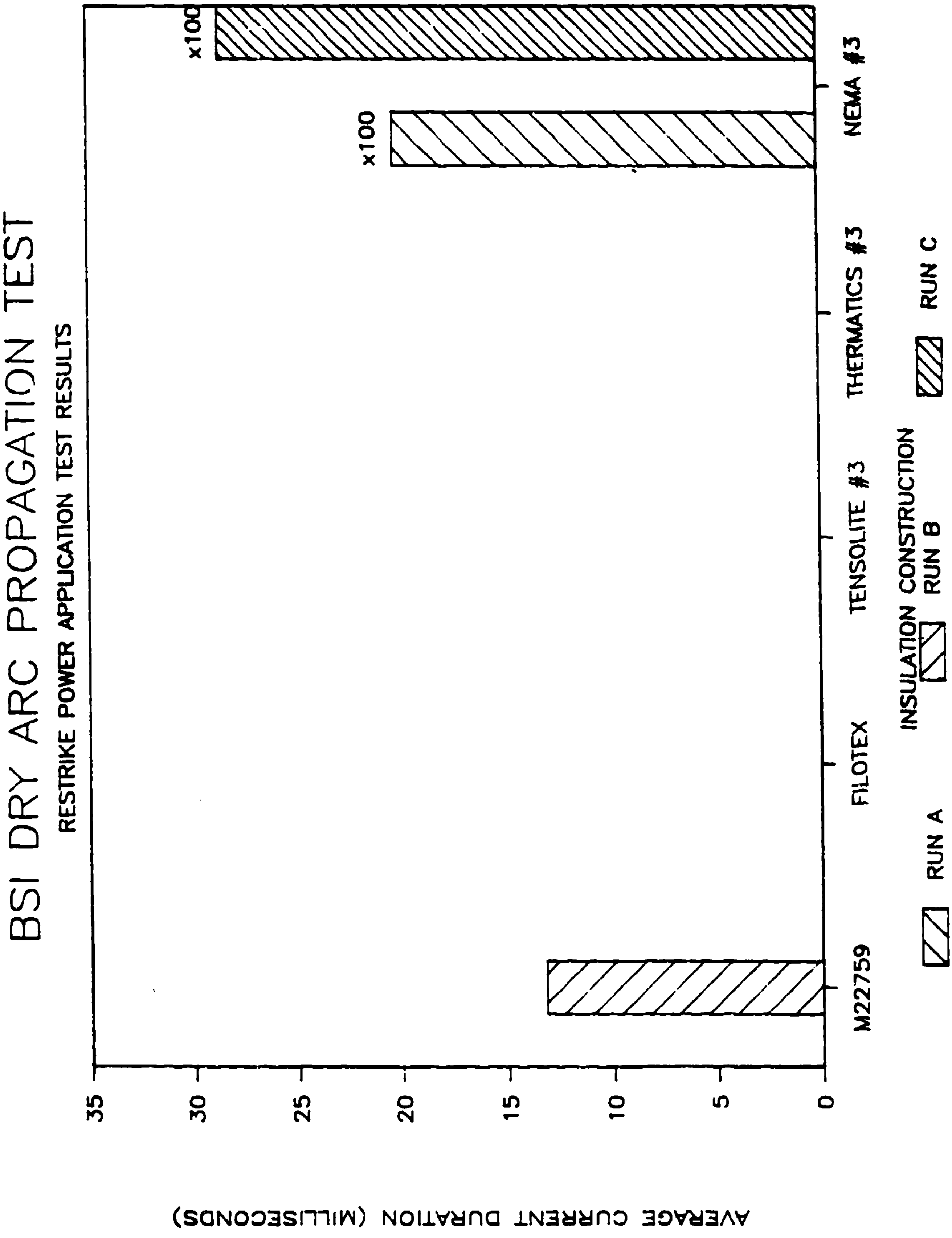


FIGURE 5.4 - BSI DRY ARC PROPAGATION TEST, RESTRIKE POWER APPLICATION TEST RESULTS

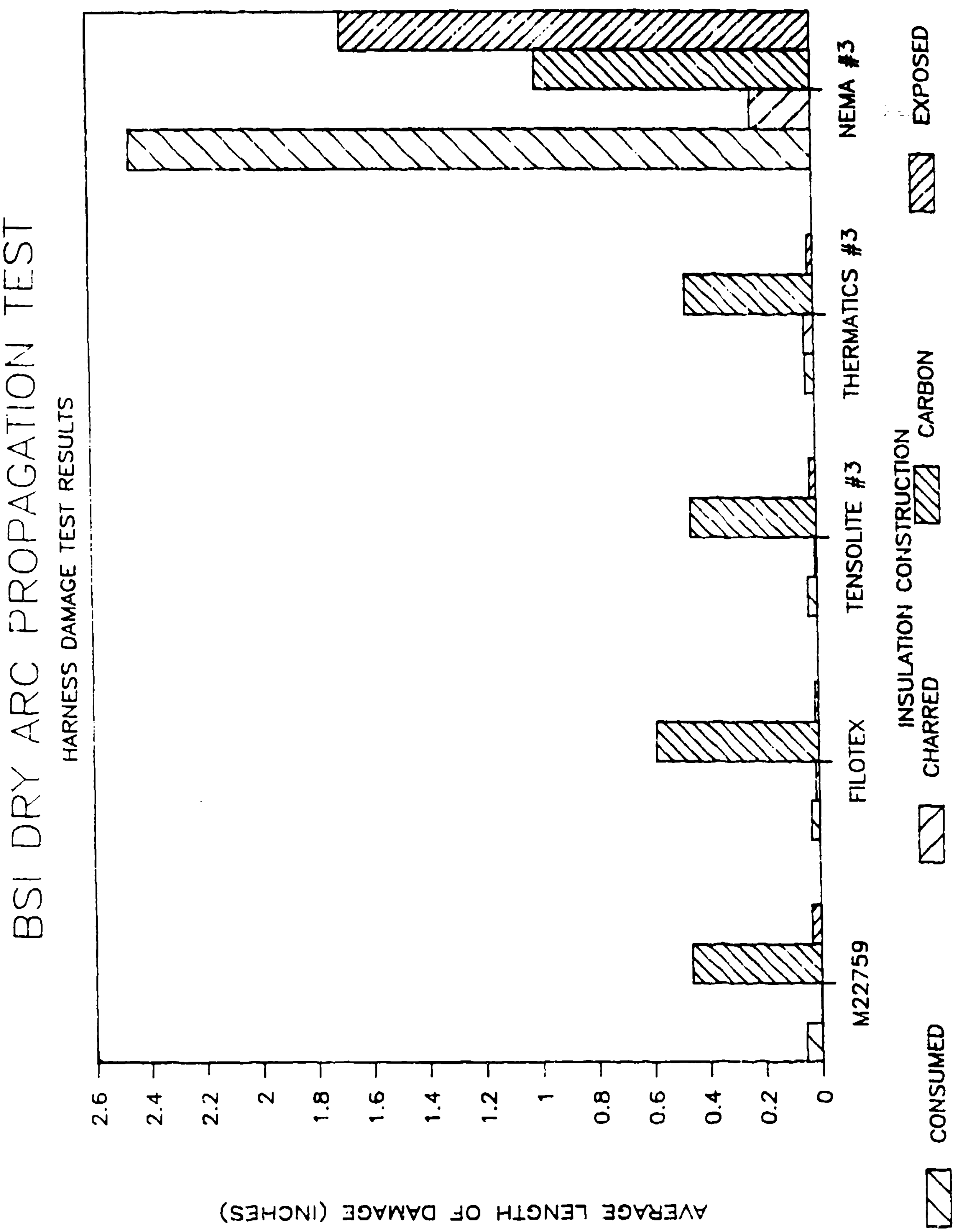


FIGURE 5.5 - BSI DRY ARC PROPAGATION TEST, HARNESS DAMAGE TEST RESULTS

FIGURE 5.6 - BSI DRY ARC PROPAGATION TEST SETUP

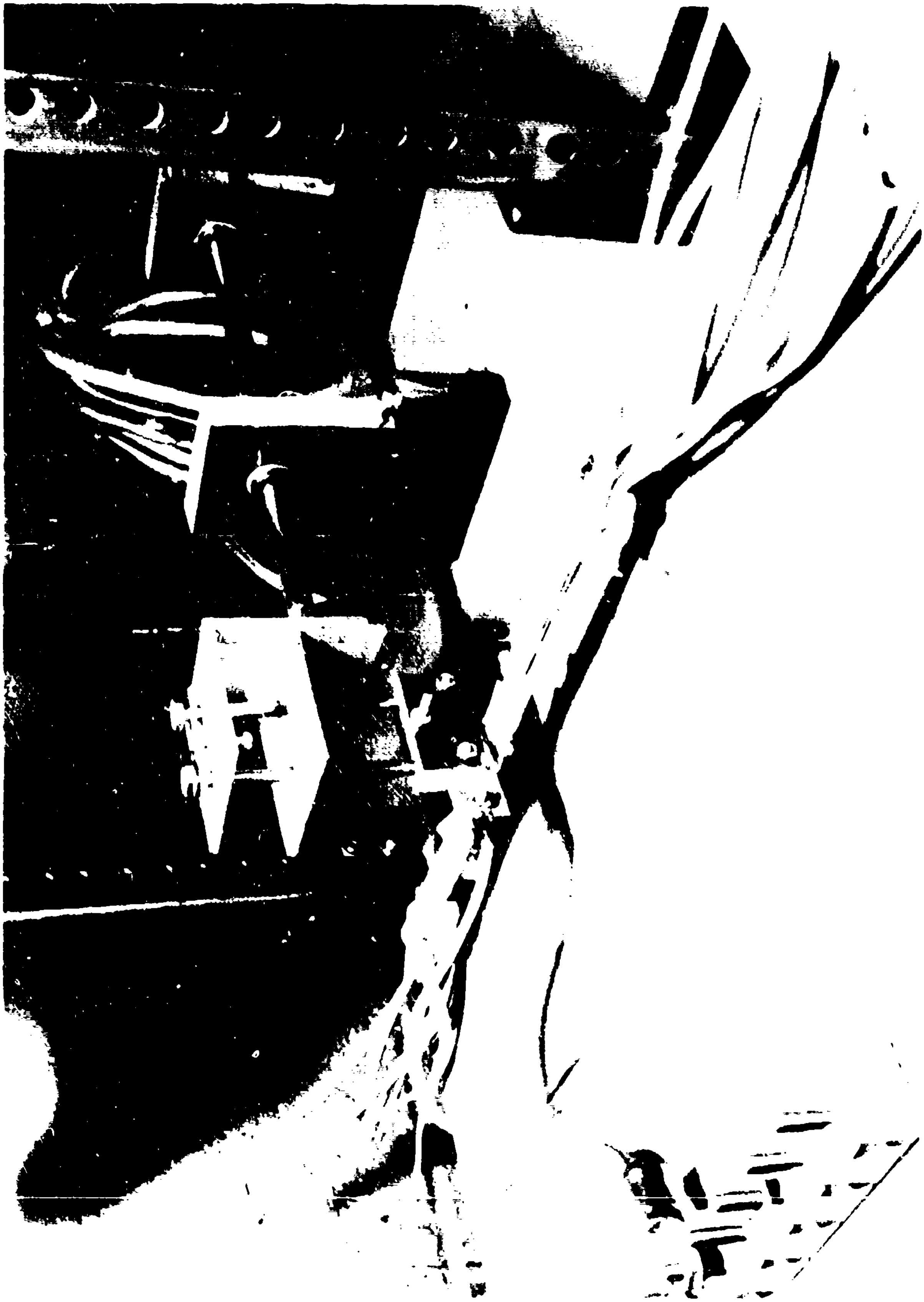


FIGURE 5.[illegible] - WSI DRY ARC PROPAGATION TEST SETUP

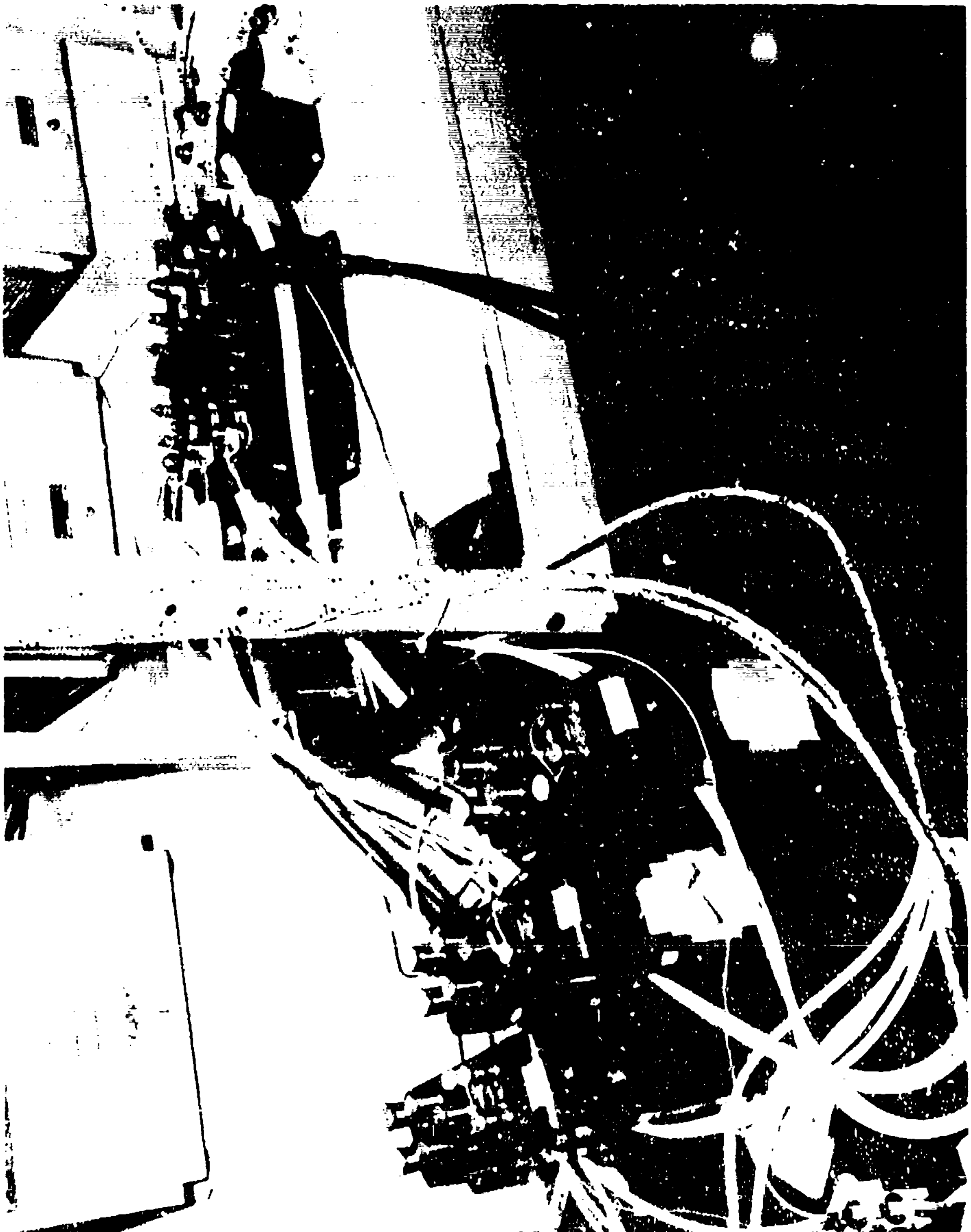
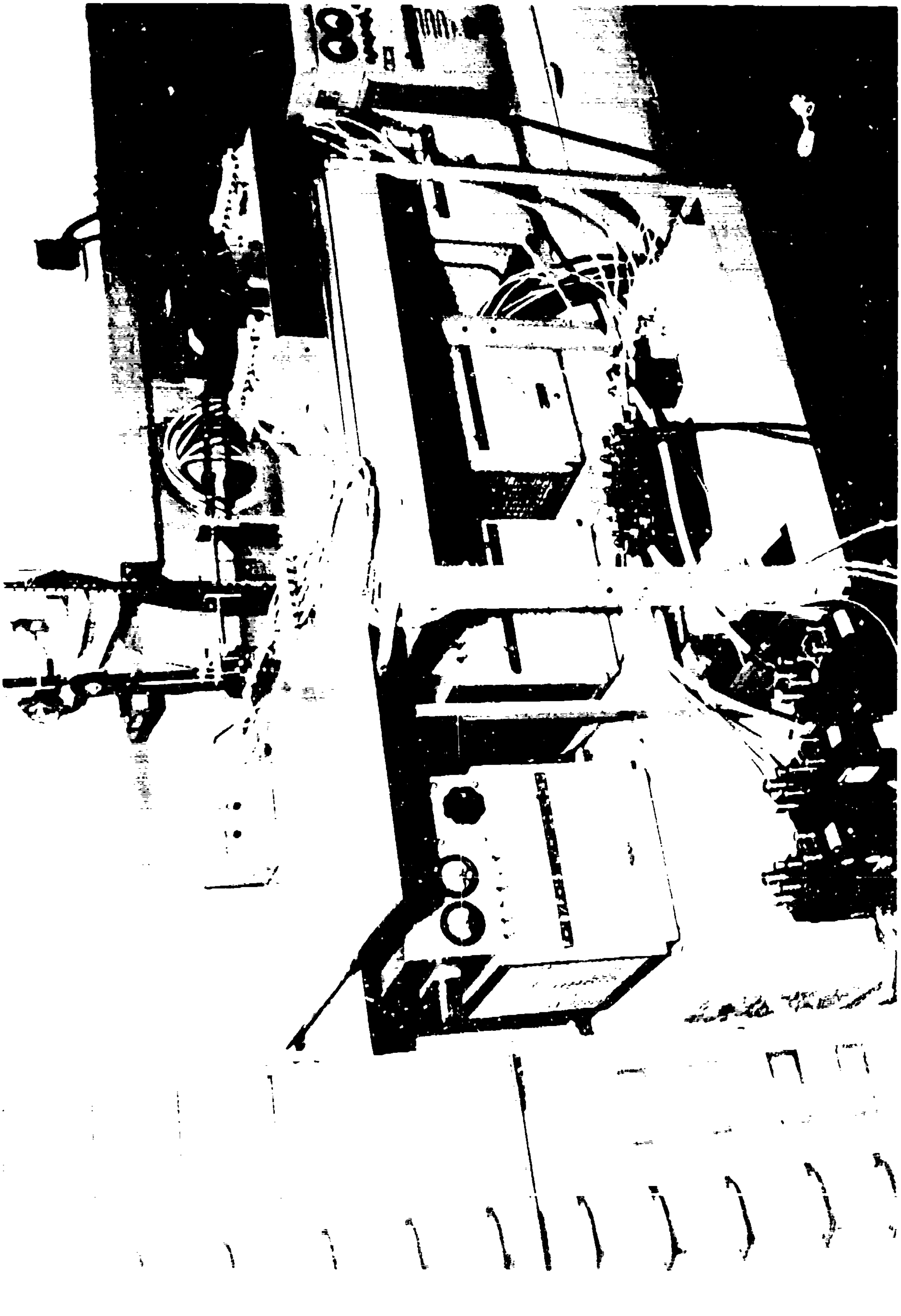


FIGURE [illegible] - [illegible] DRY ARC PROPAGATION TEST CURRENT SENSORS



[illegible] - BST DRY ARC PROPAGATION TEST SETUP

5.3 ELECTRICAL TESTS

5.3.1 DIELECTRIC CONSTANT.

5.3.1.1 Scope: The Dielectric Constant Test was used to determine the dielectric constant, K, of the insulation.

5.3.1.2 Reference Procedure: The Dielectric Constant Test was conducted according to Method 501 of SAE AS4373 by each insulating manufacturer. SAE AS4373 references Method 6271 of Federal Test Method Standard 228 for equipment specifications and test procedure. Method 6271 references Method 1011 of Federal Test Method Standard 228 to acquire the insulation thickness using a micrometer caliper.

5.3.1.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. One unconditioned specimen was cut for each sample of wire tested. The specimens were cut to a length of 15 feet with insulation removed from both ends to apply a potential to the specimen's conductor.

5.3.1.4 Test Equipment: A capacitance bridge, with an accuracy to 1 micro-Farad, was used to acquire the capacitance value of the specimen. An ac power supply,

set at a frequency of 1000 Hertz, was used to to supply power to the specimen and the bridge. The bridge was configured to have one end of the specimen conductor grounded.

A micrometer, accurate to 0.001 inches, was used to acquire the insulation and conductor diameters.

5.3.1.5 Test Procedure: The specimen insulation diameter and conductor diameter were determined according to Method 1011 of Federal Test Method Standard 228. The average insulation diameter and the average conductor diameter were determined.

The capacitance of the insulation was determined according to Method 6271 of Federal Test Method Standard 228. The center 10 foot segment of the specimens was submerged in a distilled water bath for 336 hours (Barcel and Independent was 334 hours) at room temperature. At the completion of the soaking period, a voltage potential at 1000 Hertz was applied across the specimen and bridge to determine the capacitance value.

The diameter measurements and the capacitive measurements were used to calculate the dielectric constant, K, of the insulation according to the following relationship:

$$K = 13{,}600\ C \log_{10} (D / d)$$

where:

C = capacitance of the specimen in micro-Farads

D = diameter of the insulation in inches

d = diameter of the conductor in inches

The calculated value for the dielectric constant reported by each manufacturer was supplied to MCAIR.

5.3.1.6 Test Results: The calculated values of the dielectric constants are presented in Tables 5.12 through 5.14 with graphical representation of the data presented in Figure 5.10.

TABLE 5.12 - DIELECTRIC CONSTANT TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	DIELECTRIC CONSTANT, K	REPORTED BY
201	M81381	2.730	INDEPENDENT
206	M22759	2.600	BRAND REX
236	FILOTEX	2.690	FILOTEX
241	TENSOLITE #3	2.175	TENSOLITE
246	THERMATICS #3	2.860	THERMATICS
256	NEMA #3	2.550	CHAMPLAIN

TABLE 5.13 - DIELECTRIC CONSTANT TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	DIELECTRIC CONSTANT, K	REPORTED BY
202	M81381	3.119	TENSOLITE
207	M22759	2.240	CHAMPLAIN
237	FILOTEX	2.540	FILOTEX
242	TENSOLITE #3	2.240	TENSOLITE
247	THERMATICS #3	3.200	THERMATICS
257	NEMA #3	2.810	CHAMPLAIN

TABLE 5.14 - DIELECTRIC CONSTANT TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	DIELECTRIC CONSTANT, K	REPORTED BY
203	M81381	3.358	BARCEL
208	M22759	2.600	BRAND REX
238	FILOTEX	2.650	FILOTEX
243	TENSOLITE #3	2.386	TENSOLITE
248	THERMATICS #3	2.940	THERMATICS
258	NEMA #3	2.550	BRAND REX

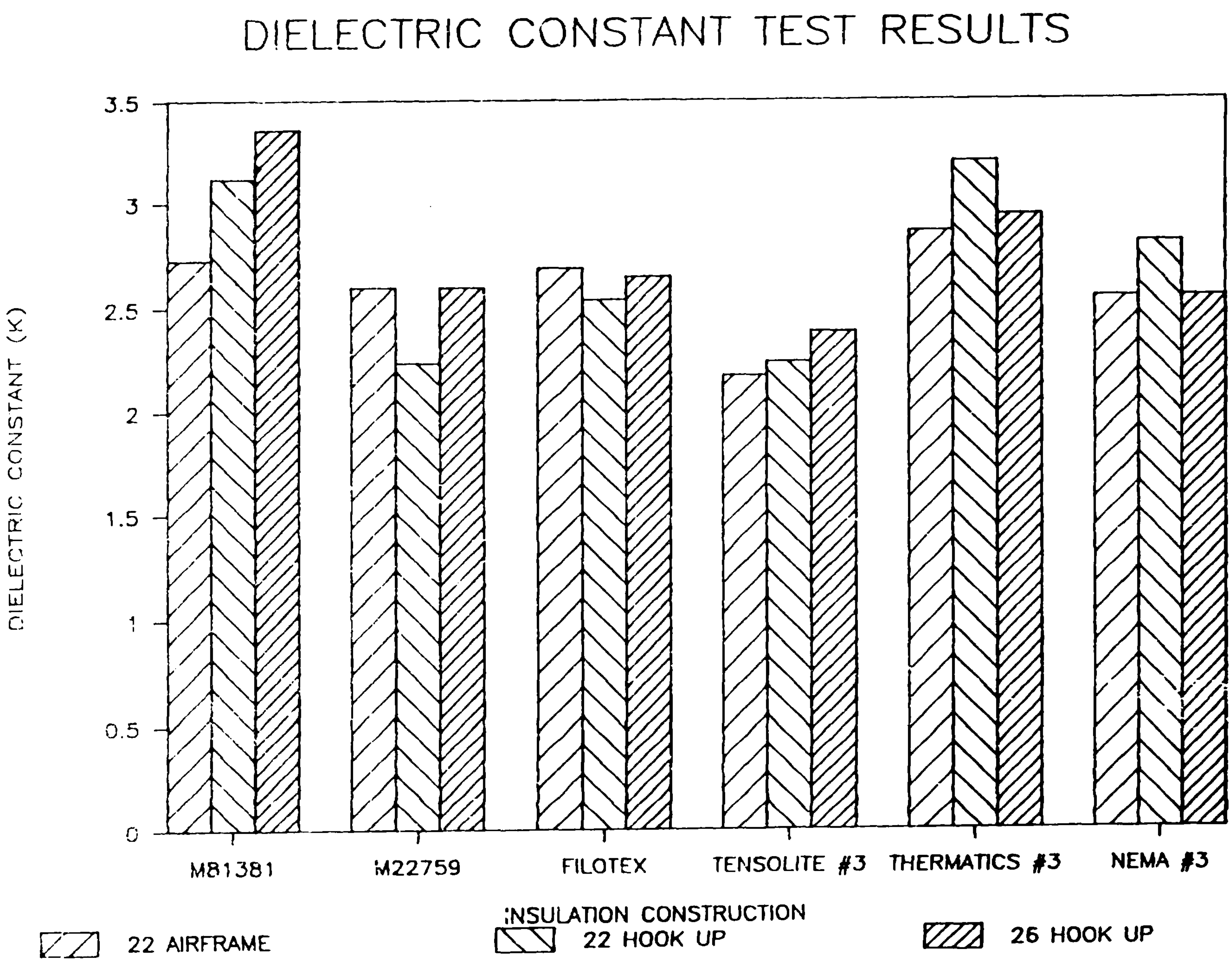


FIGURE 5.10 - DIELECTRIC CONSTANT TEST RESULTS

5.3.2 CORONA INCEPTION AND EXTINCTION VOLTAGES.

5.3.2.1 AC CORONA INCEPTION AND EXTINCTION VOLTAGES.

5.3.2.1.1 **Scope:** The Corona Inception and Extinction Voltage Test was used to determine the corona inception and extinction voltage of an insulated wire sample using a 400 Hertz power source.

5.3.2.1.2 **Reference Procedure:** The Corona Inception and Extinction Voltage Test was conducted in general accordance with the procedure defined in Method 502 of SAE AS4373. This procedure references ASTM D3032, section 25, for the procedure and ASTM 1868, section 7, for the test equipment. The test was conducted using a 400 Hertz power supply at both sea level (758 Torr) and 60,000 feet (49 Torr).

5.3.2.1.3 **Specimens:** Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Three unconditioned wire specimens were cut for each test. The specimens were cut to a length of 34 inches with a quarter inch of insulation removed from both ends. The specimens were wrapped for 10 turns and equally spaced at two wraps per inch around a mandrel which was approximately ten times the diameter of the

specimens. The specimens were secured to the mandrel with half inch, three mil, Teflon tape. The ends of the specimen were then twisted together and a spade terminal was crimped onto the conductor to attach the specimen to the power strip.

5.3.2.1.4 Test Equipment: Carbon steel drill rods were used for mandrels. The mandrel diameters used were 0.5 inches for 22 gauge, 8.5 mil wall, wire; 0.4375 inches for 22 gauge, 5.8 mil wall, wire; and 0.3078 inches for 26 gauge, 5.8 mil wall, wire. The mandrels and specimens were mounted in a phenolic holding fixture. The specimens were connected to a power strip while each mandrel was connected to an individual return line. When one specimen was being tested, all the other return lines were connected together.

A Tektronix 485, 100 megahertz, Oscilloscope (MD 077678), was used to detect corona discharges by monitoring the voltage across a 51 k-ohm resistor that connected the individual drill rod to the return line of the power supply.

A 400 Hertz power supply, variable from 0 to 1600 volts rms, used a 60 to 400 Hertz Frequency Converter (MD 115547), Model SPC-6-750, whose output was controlled by a Varitran Variac (MD 160354). The Variac controlled output voltage was connected to three Stancor transformers to achieve the 0 to 1600 volts rms output

voltage. The output voltage was monitored by a Fluke 8050A Digital Multimeter (MD 011813) in conjunction with a Fluke 80K-6 High Voltage Probe (MDC 030296).

The test was conducted in a Tenney 3 Foot Environmental Chamber (MD 066051) which controlled temperature, altitude, and humidity.

Photographs of the test setup and equipment are presented in Figures 5.14 through 5.16.

5.3.2.1.5 Test Procedure: The power supply output was connected to one of the three power strips on the fixture. Each specimen's mandrel was attached to the power supply's return line by a 51 k-ohm resistor. The voltage from the power supply was increased at a rate no greater than 50 volts per second until continuous corona discharges were observed on the positive half cycle of the ac waveform. After the inception voltage was determined, the voltage was lowered gradually until the discharges were no longer detectable and this voltage was recorded as the extinction value. All ac voltages recorded are root mean square values.

The test was conducted at sea level and 60,000 feet with an untested set of specimens used for each test. The results of the three test specimens at sea level were averaged together to achieve an average inception voltage and an average extinction voltage. This procedure was followed for the specimens at altitude and the test

results were recorded.

5.3.2.1.6 Test Results: The Thermatics #3 specimens exhibited unusual corona characteristics. The insulation had an unusually high leakage current at voltage with no corona observed on the oscilloscope. A second set of specimens were tested at sea level and the same characteristics were observed.

An insulation integrity test was conducted by performing a 500 volt dc Insulation Resistance Test. The test was conducted with the specimen wrapped on the rod. The positive lead of the supply was attached to the specimen conductor and the negative lead of the supply to the carbon steel rod. The 500 volts dc was applied and all specimens measured had an insulation resistance greater than 100 megohms.

A Voltage Withstand Test, Method 510 of SAE AS4373, was also conducted on the specimens at 2500 volts at 60 Hertz. If they passed 2500 volts, then the specimens were tested at 3000 volts. The specimens were soaked for four hours in a 5% salt (NaCl) solution with 0.1% wetting agent (Aerosol) added. After the soak time, the specimens were subjected to the Voltage Withstand Test for a period of one minute. A leakage current measurement was acquired for each specimen.

All Thermatics #3 specimens passed the Voltage Withstand Test at 3000 volts but relatively high leakage

currents were recorded. The average values obtained were 627 μA for 22 gauge, 8.6 mil wall, airframe specimens; 667 μA for 22 gauge , 5.8 mil wall; and 467 μA for the 26 gauge, 5.8 mil wall specimens.

A 26 gauge specimen that was thermally aged for 1000 hours at 200°C (392°F) was tested for corona. The specimen achieved a greater voltage potential before it was affected by power supply loading.

The investigation concluded that the anomalies observed on the Thermatics #3 specimens were a result of incomplete sealing of the insulation. This conclusion was corroborated by the manufacturer.

The average inception and extinction voltages for the specimens at sea level and 60,000 feet are presented in Tables 5.15 through 5.17 with graphical representation of the data presented in Figures 5.11 through 5.13. The Thermatics #3 values identified with an asterisk (*) are not corona values, but values at which power supply loading came into effect.

TABLE 5.15 - AC CORONA INCEPTION AND EXTINCTION VOLTAGE OF 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

		ALTITUDE: SEA LEVEL		ALTITUDE: 60,000 FT.	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE CORONA INCEPTION VOLTAGE (VOLTS RMS)	AVERAGE CORONA EXTINCTION VOLTAGE (VOLTS RMS)	AVERAGE CORONA INCEPTION VOLTAGE (VOLTS RMS)	AVERAGE CORONA EXTINCTION VOLTAGE (VOLTS RMS)
101	M81381	1290	1126	446	393
106	M22759	1387	1100	462	393
136	FILOTEX	1421	1232	469	394
141	TENSOLITE #3	1485	1196	472	394
146	THERMATICS #3	*623	*531	437	391
156	NEMA #3	1345	1026	436	390

TABLE 5.16 - AC CORONA INCEPTION AND EXTINCTION VOLTAGE OF 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

		ALTITUDE: SEA LEVEL		ALTITUDE: 60,000 FT.	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE CORONA INCEPTION VOLTAGE (VOLTS RMS)	AVERAGE CORONA EXTINCTION VOLTAGE (VOLTS RMS)	AVERAGE CORONA INCEPTION VOLTAGE (VOLTS RMS)	AVERAGE CORONA EXTINCTION VOLTAGE (VOLTS RMS)
102	M81381	1009	915	391	332
107	M22759	1180	1008	396	342
137	FILOTEX	1197	1004	420	345
142	TENSOLITE #3	1268	1066	460	344
147	THERMATICS #3	*571	*512	407	347
157	NEMA #3	1157	975	404	349

TABLE 5.17 - AC CORONA INCEPTION AND EXTINCTION VOLTAGE OF 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

		ALTITUDE: SEA LEVEL		ALTITUDE: 60,000 FT.	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE CORONA INCEPTION VOLTAGE (VOLTS RMS)	AVERAGE CORONA EXTINCTION VOLTAGE (VOLTS RMS)	AVERAGE CORONA INCEPTION VOLTAGE (VOLTS RMS)	AVERAGE CORONA EXTINCTION VOLTAGE (VOLTS RMS)
103	M81381	1106	892	394	339
108	M22759	1146	944	421	346
138	FILOTEX	1121	948	413	347
143	TENSOLITE #3	1287	1079	465	348
148	THERMATICS #3	*567	*480	392	338
158	NEMA #3	1192	1046	423	347

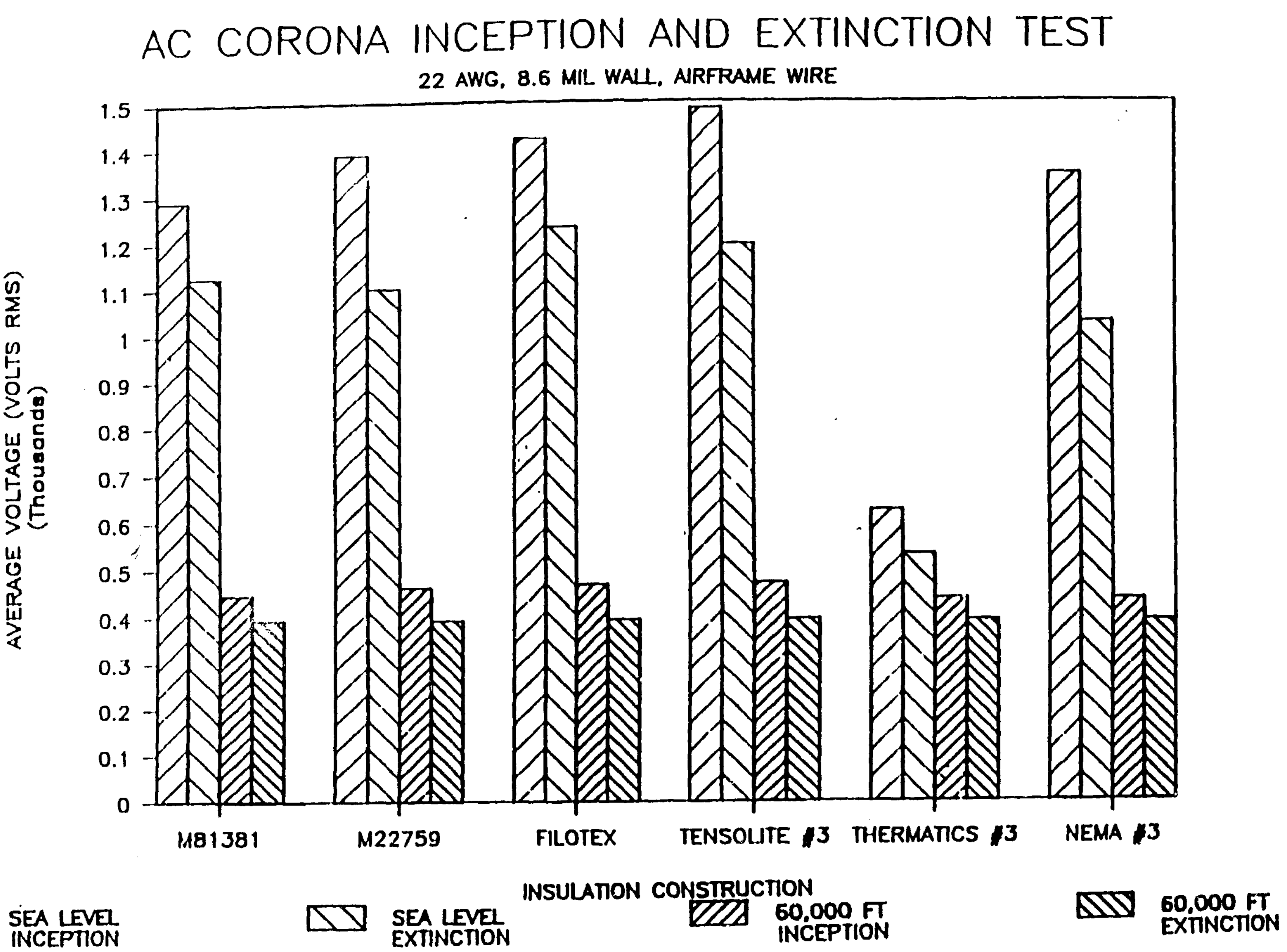


FIGURE 5.11 - AC CORONA INCEPTION AND EXTINCTION TEST, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

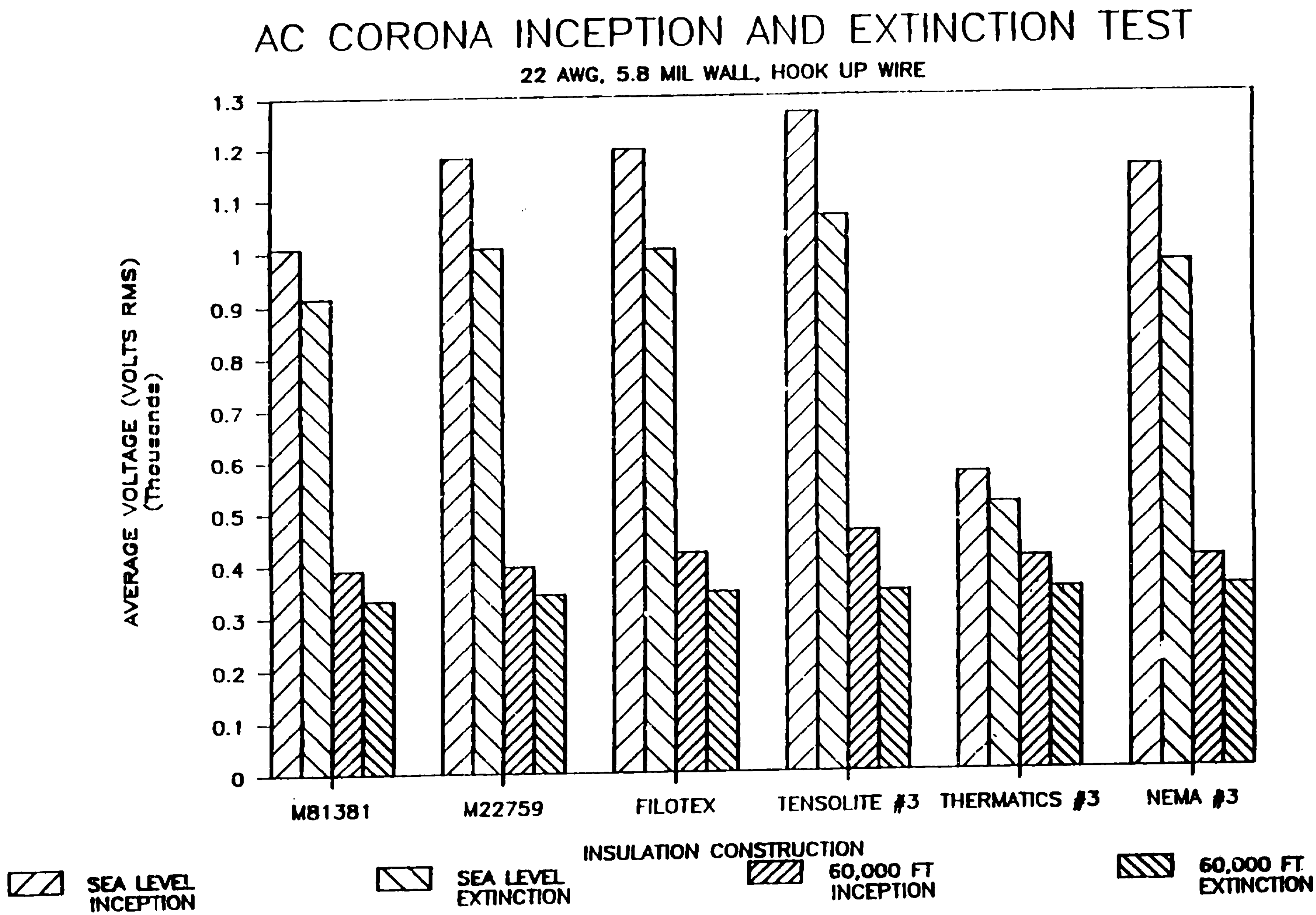


FIGURE 5.12 - AC CORONA INCEPTION AND EXTINCTION TEST, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

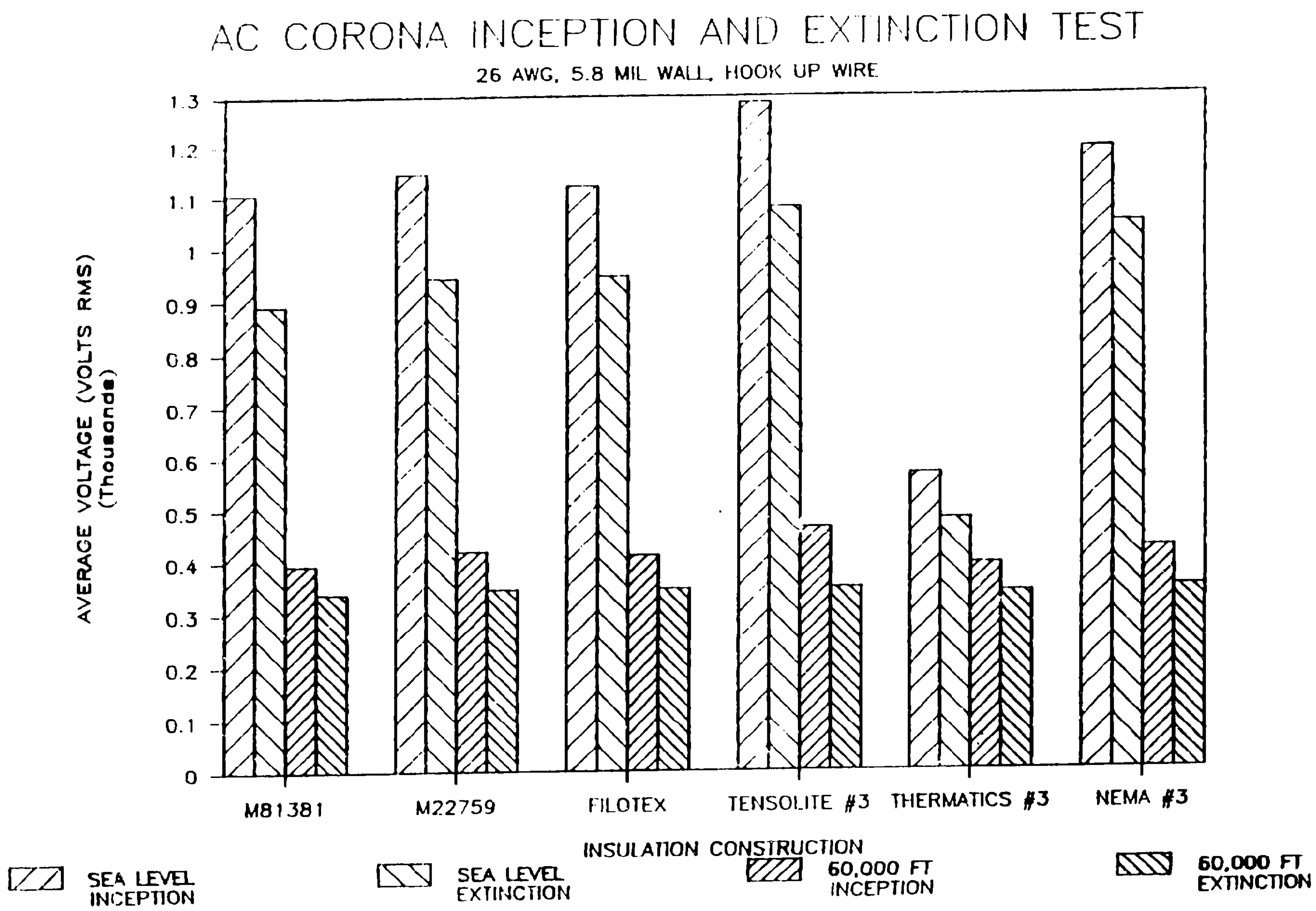


FIGURE 5.13 - AC CORONA INCEPTION AND EXTINCTION TEST, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

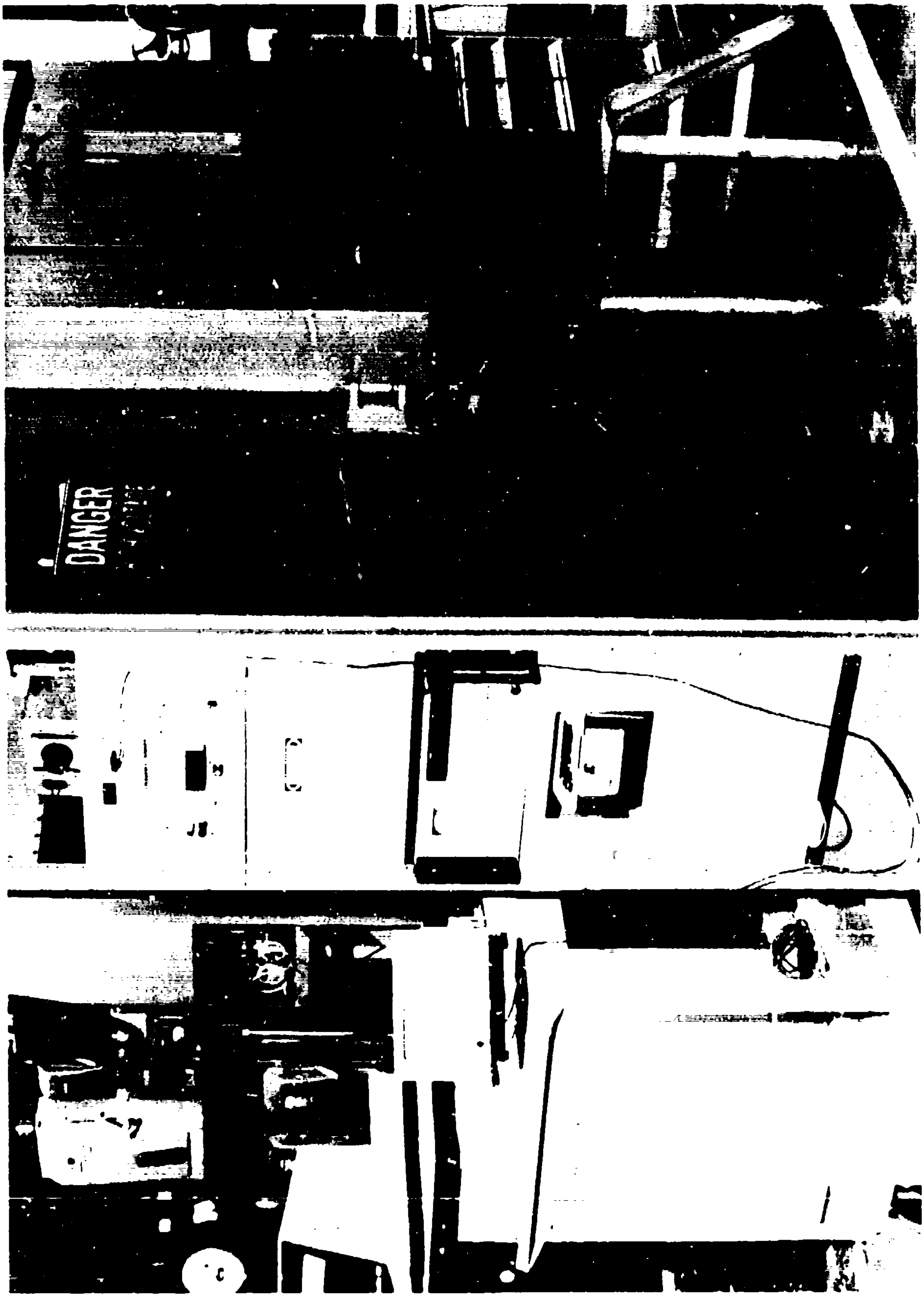


FIGURE 5.14 - AC CORONA INCEPTION AND EXTINCTION TEST CHAMBER

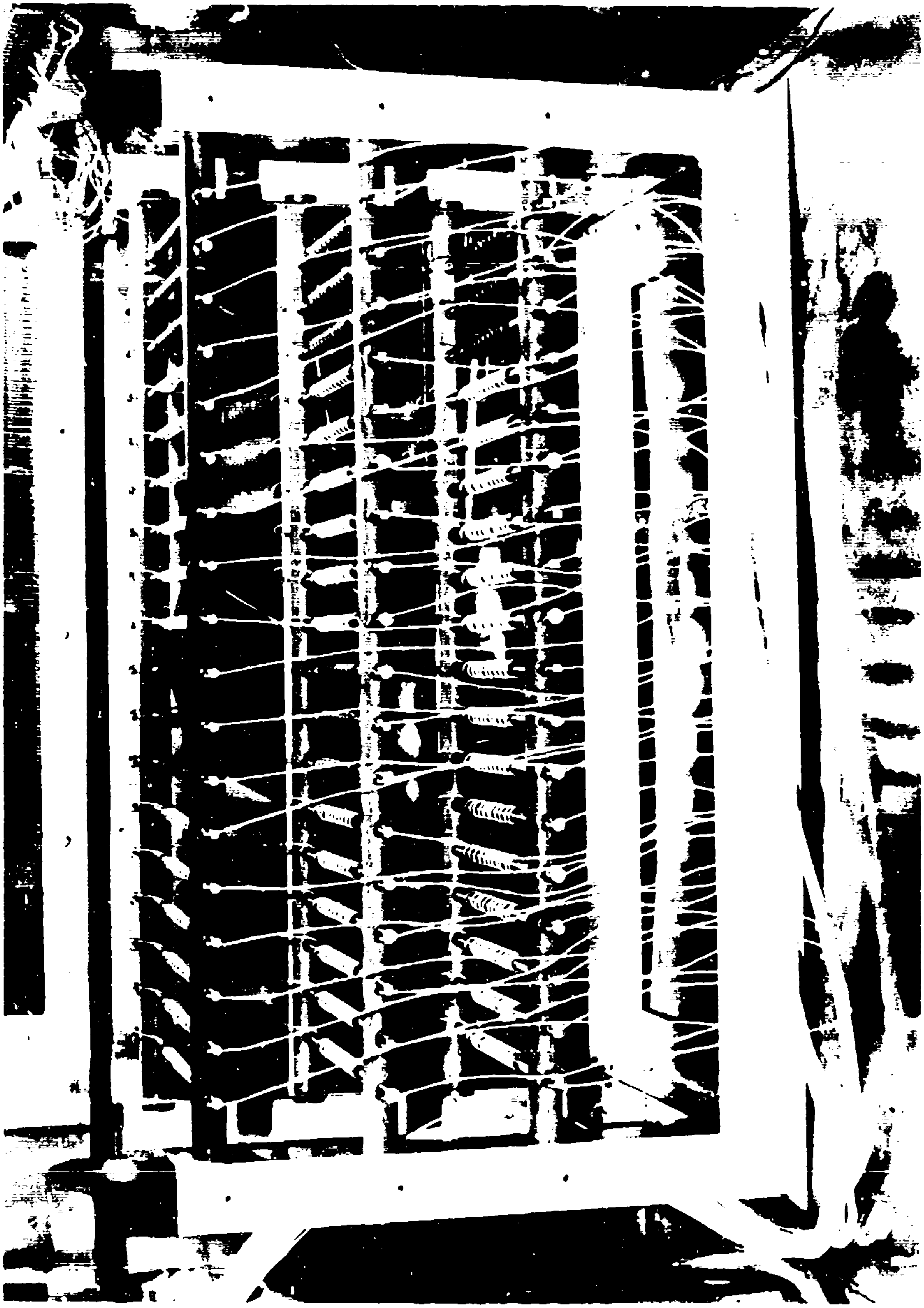


FIGURE 5.15 - AC CORONA INCEPTION AND EXTINCTION TEST RACK

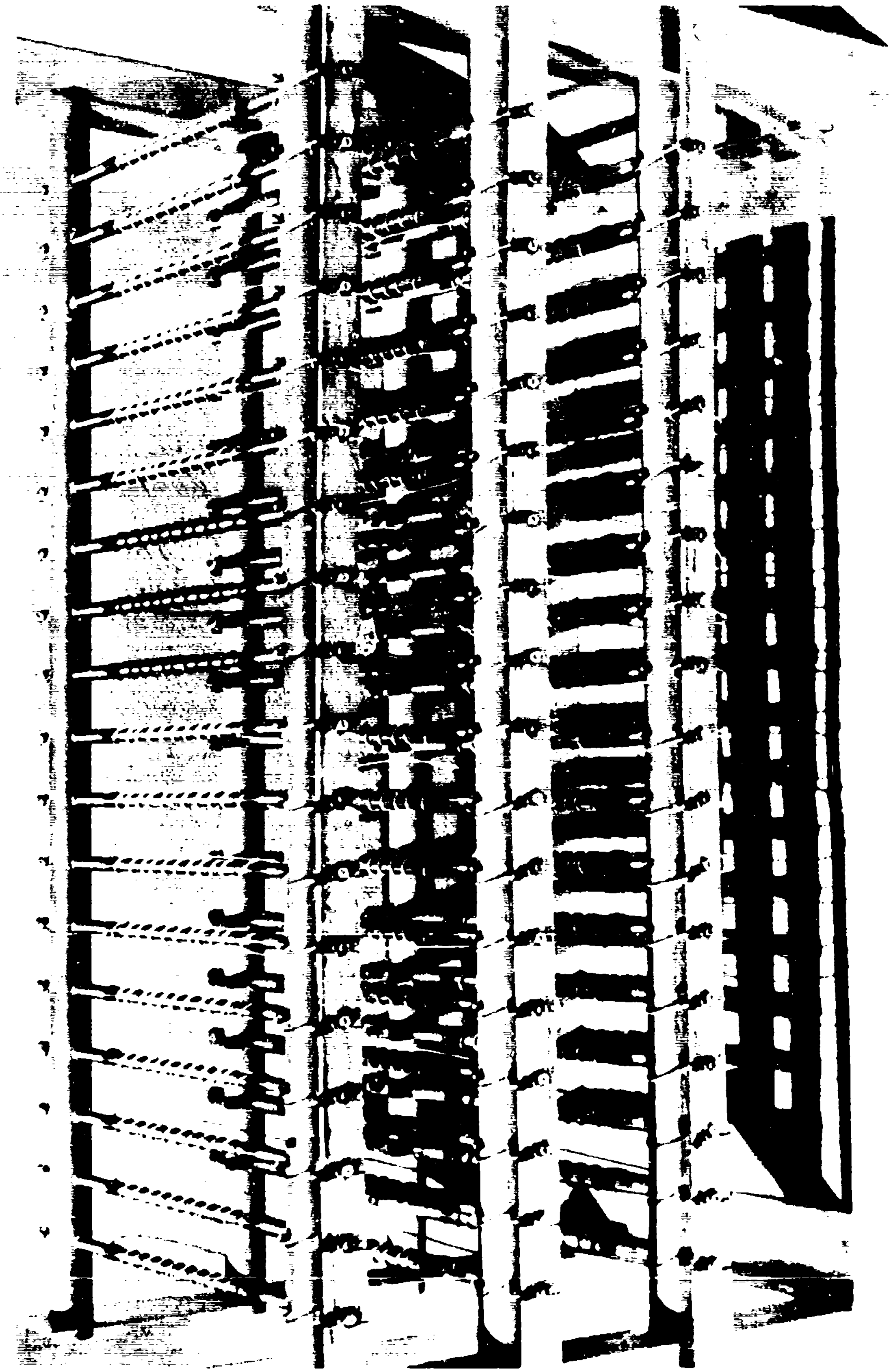


FIGURE 5.16 - AC CORONA INCEPTION AND EXTINCTION TEST RACK

5.3.2.2 DC CORONA INCEPTION AND EXTINCTION VOLTAGES.

5.3.2.2.1 Scope: The Corona Inception and Extinction Voltage Test was intended to determine the steady state corona inception and extinction voltage of an insulated wire sample using a dc power source.

5.3.2.2.2 Reference Procedure: The Corona Inception and Extinction Voltage Test was conducted in general accordance with the procedure defined in Method 502 of SAE AS4373. The test was conducted using a dc power supply at sea level (758 Torr). The test was not conducted at 60,000 feet (49 Torr) due the problems encountered in detecting steady state dc corona at sea level.

5.3.2.2.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Three unconditioned wire specimens were cut for each sample. The specimens were cut to a length of 34 inches and had a quarter inch of insulation removed from both ends. The specimens were wrapped for 10 turns and equally spaced at two wraps per inch around a mandrel which was approximately ten times the diameter of the specimens. The specimens were secured to the mandrel with half inch, three mil, Teflon tape. The ends of the

specimen were then twisted together and a spade terminal was crimped onto the conductor to apply power to the specimen.

5.3.2.2.4 Test Equipment: Carbon steel drill rods were used for mandrels. The mandrel diameters used were 0.5 inches for 22 gauge, 8.5 mil wall, wire; 0.4375 inches for 22 gauge, 5.8 mil wall, wire; and 0.3078 inches for 26 gauge, 5.8 mil wall, wire. The mandrels and specimens were mounted in a phenolic holding fixture. The specimens were connected to the positive terminal of the power supply while the mandrel was connected to the power supply return.

A Universal Voltronics 10,000 Volt dc power supply (MD 64437-10) and a Beckman 25,000 Volt Insulation Breakdown Tester were used to conduct the test. The output voltage of the power supply was monitored with a Fluke 80K-40 High Voltage Probe (MD 030296) and a Soltec (SMR) Signal Memory Recorder (MD 117327). The corona detection circuit was placed in series with the specimen and consisted of a voltage divider coupled to the Soltec SMR by a 690 pico-farad capacitor. The voltage divider consisted of a pair of 51,000 ohm, 0.25 watt, resistors. The Soltec SMR had a resolution of 0.25 millivolts with a sample rate of one micro-second. The specimen and mandrel were enclosed in a cardboard box to seal off all light entry. A United Technologies Fiber Optic Power

Meter (MD 092804) and detector (MD C181796) were used to detect light emission from dc corona.

5.3.2.2.5 Test Procedure: The positive terminal of the power supply was connected to the specimen's spade terminal. The carbon steel drill rod was connected to the return of the supply through the corona detection circuit. The dc voltage from the power supply was slowly increased at a rate no greater than 50 volts per second. At each 100 volt increment, the voltage was stabilized and the Soltec was armed to trigger off of a 25 millivolt or greater signal. The operator waited 30 seconds for a trigger before manually triggering the Soltec to observe the signal. If no high frequency transients were observed, the power supply voltage was incremented to the next voltage value. The traces monitored for low level, sporadic, high frequency transients to determine the steady state inception voltage. The voltage was then lowered at 100 volt increments with the 30 second wait to detect when the high frequency, sporadic, steady state discharges were no longer detected. This was reported as the extinction voltage.

The test was conducted only at sea level due to the problems encountered in detecting steady state dc corona.

5.3.2.2.6 Test Results: No data was obtained because of the problems in confirming that the steady state transients observed were corona. The signal waveforms acquired could not be confirmed as corona coming from the specimen under test. When voltages greater than 5000 volts were achieved, arcing was occurring at terminals where leads were attached. The terminals were potted with RTV Silicone to prevent any false signals. The voltage was raised to the Universal Voltronics 10,000 Volt power supply's limit. No corona signature was identified at steady state. A Beckman 25,000 Volt Insulation Breakdown Tester was used to acquire a higher voltage level. The supply could only be raised to 20,000 volts before arcing was audible by the human ear within the power supply. The ripple from the power supply made it difficult to decipher any high frequency transients in the signal acquired. No high pass filter was placed on the power supply because the components were not available.

The fiber optic power meter did not detect any light emission from the specimen because it was not sensitive to wavelengths below 400 nano-meters. The corona spectrum is typically in the ultra-violet region of the spectrum.

The problems associated with not being able to detect steady state dc corona were primarily due to unavailability of the special equipment needed to conduct the task. A high voltage corona free power supply with

high voltage insulated wire would be required to guarantee that the discharges detected were a result of the specimen under test and not the test setup. A recording instrument sensitive enough to detect the magnitude of the pulses with a bandwidth of at least 100 megahertz would be required to observe the corona signature. An integrating circuit in conjunction with a pulse counter would be needed to detect and monitor the number of high frequency discharges.

5.3.3 SURFACE RESISTANCE.

5.3.3.1 Scope: The Surface Resistance Test was used to determine the surface resistance of a finished wire sample.

5.3.3.2 Reference Procedure: The Surface Resistance Test was conducted according to Method 506 of SAE AS4373 by each insulation manufacturer. SAE AS4373 references Method 6041 of Federal Test Method Standard 228.

5.3.1.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire and 22 gauge, 5.8 mil wall, hook up wire. One unconditioned specimen was cut to a length of six inches for each sample of wire tested.

The specimens were cleaned first with distilled water, then Isopropyl Alcohol, and then rinsed with distilled water. The specimens were dried in an air circulating oven. Care was taken in the handling of the specimens so as not to introduce any contaminants that may interfere with the test results.

5.3.3.4 Test Equipment: A test chamber was required that was capable of maintaining a temperature of 25±1°C (77±2°F) at a relative humidity level of 95±4%. The chamber was instrumented to monitor temperature and relative humidity. The chamber was configured so that the

specimens were placed at least one inch from any wall of the chamber. The resistance between the test lead wires and the chamber was measured and guaranteed to be greater than one megohm.

An isolated 500 volt, dc power supply was used to supply power for the test. Power was supplied to the specimen by two electrodes. Each electrode was soldered to a coil of several turns of 27 gauge tin coated copper wire. The tin coated copper wire was snugly wrapped around each specimen for several turns, each turn separated by one inch. A shunt was placed in series with the power supply to determine the amount of leakage current.

A 2500 volt, 60 Hertz, power supply was used in the test to check for insulation integrity.

5.3.3.5 Test Procedure: The specimen was placed in the test chamber with the coils snugly around the specimen. The electrodes were placed on the specimen at a 1.0 inch spacing from the nearest edges. The chamber was closed and the specimens were conditioned for 96 hours at a relative humidity level of 95±4% at a temperature of 25±1°C (77±2°F). At the completion of the conditioning, a 500 volt dc potential was applied between the two electrodes on the surface of the specimen. The voltage and leakage current values were acquired one minute after the potential was applied.

The power supply was changed to the 2500 volt, 60 Hertz, power supply. The potential was applied for one minute to check for insulation integrity. The test checked for arcing, smoking, dielectric failure, or any other anomalies.

Approximately 15 to 30 minutes after the insulation integrity test, the surface resistance was remeasured using the dc power supply.

The surface resistance was calculated by multiplying the applied dc voltage by the overall diameter of the specimen and dividing by the leakage current as shown by the following relationship:

$$R = (V_{dc} \times D) / I_{leakage}$$

where:

R = insulation resistance in megohms per inch

V_{dc} = applied dc potential in volts

D = overall diameter of specimen in inches

$I_{leakage}$ = leakage current in micro-amps

The calculated surface resistance values were reported to MCAIR from the manufacturers.

5.3.3.6 Test Results: The acquired surface resistance values supplied to MCAIR are presented in Tables 5.18 through 5.19 with graphical representation of the data presented in Figure 5.17.

TABLE 5.18 - SURFACE RESISTANCE TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	SURFACE RESISTANCE (MEGOHMS PER INCH)	REPORTED BY
101	M81381	11.00	INDEPENDENT
106	M22759	22,575.33	BRAND REX
236	FILOTEX	18.50	FILOTEX
141	TENSOLITE #3	52.14	TENSOLITE
146	THERMATICS #3	7,520.00	THERMATICS
156	NEMA #3	230,000.00	CHAMPLAIN

TABLE 5.19 - SURFACE RESISTANCE TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	SURFACE RESISTANCE (MEGOHMS PER INCH)	REPORTED BY
102	M81381	7,515.00	TENSOLITE
107	M22759	300,000.00	CHAMPLAIN
237	FILOTEX	255.00	FILOTEX
142	TENSOLITE #3	72.48	TENSOLITE
147	THERMATICS #3	3,360.00	THERMATICS
157	NEMA #3	140,000.00	CHAMPLAIN

SURFACE RESISTANCE TEST RESULTS

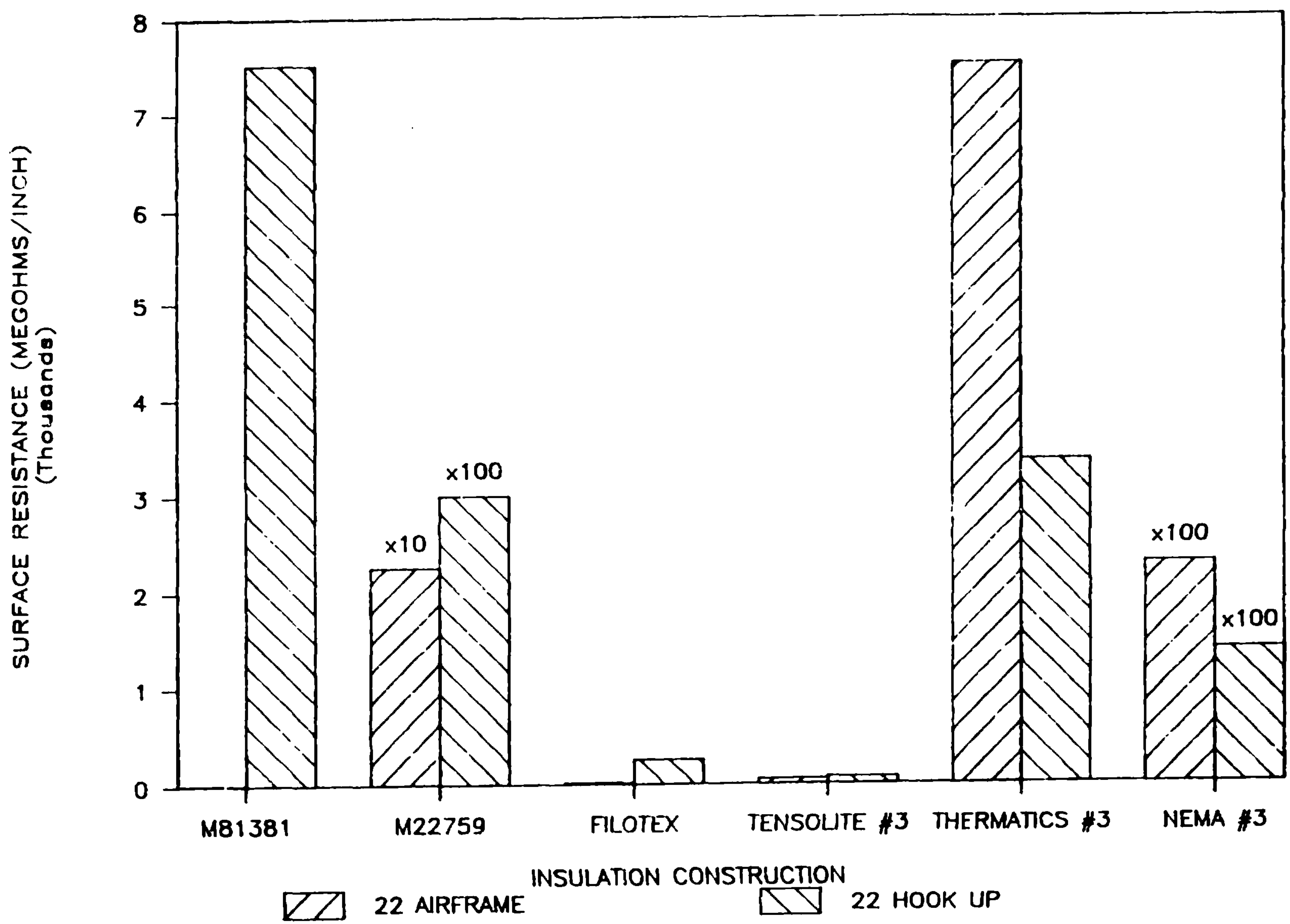


FIGURE 5.17 - SURFACE RESISTANCE TEST RESULTS

5.3.4 TIME/CURRENT TO SMOKE.

5.3.4.1 Scope: The Time/Current to Smoke Test was used to determine the time and current at which a finished wire or cable specimen produced smoke.

5.3.4.2 Reference Procedure: The test was performed by Douglas Aircraft Company (DAC) according to the procedure outlined in Method 507 of SAE AS4373.

5.3.4.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; 26 gauge, 5.8 mil wall, hook up wire; 22 gauge, two conductor, shielded and jacketed cable; and 26 gauge, two conductor, shielded and jacketed cable. Six unconditioned specimens were cut to a length of 12 inches from each sample. A 0.5 inch segment of insulation was removed from both ends of the wire specimens. The samples were cleaned using Isopropyl Alcohol prior to testing.

The cable specimens were prepared by removing one inch of the cable jacket from both ends of the specimen. A half inch of insulation was removed from each of the primary wires on both ends of the specimens. The pair of conductors were then twisted together to provide a common point for application of power. The shield remained floating for the test. The cable jacket was cleaned with

Isopropyl Alcohol prior to testing. The cable jackets were not removed for the test.

5.3.4.4 Test Equipment: A Hewlett Packard dc power supply, Model 6453A, was used to supply power to the test specimen. The dc current was monitored using an F. W. Bell current meter, Model 1776, in series with the supply and test specimen.

A vented chamber was used to house the test and protect the operator from potentially toxic gases generated as a result of the test. The test setup was configured to suspend the test specimen horizontally in air. A black sheet of construction paper was placed behind the specimen to facilitate the observation of smoke.

A stopwatch was used to determine the time to smoke.

5.3.4.5 Test Procedure: The specimen was placed in the test setup horizontally and secured to a terminal block for power application. The test began by raising the current through the specimen to 10 amps. The stopwatch was started when the current level of ten amps was achieved. The specimen was visually monitored to detect the first sign of smoke against the black background. After 30 seconds at 10 amps, the current was raised an additional 5 amps for another 30 seconds while continually monitoring the specimen for any signs of smoke. The

current was sequentially stepped up at 5 amp increments for 30 seconds at a time until smoke was detected. The time and current values were recorded at the first sign of smoke. A description of the quantity of smoke was also recorded.

5.3.4.6 Test Results: The minimum, maximum, and average time/current to smoke values are presented in Tables 5.20 through 5.24 with a description of the average quantity of smoke observed. A graphical representation of the data is presented in Figures 5.18 through 5.22.

TABLE 5.20 - TIME/CURRENT TO SMOKE TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CURRENT/TIME (AMP/SECOND)	MAXIMUM CURRENT/TIME (AMP/SECOND)	AVERAGE CURRENT/TIME (AMP/SECOND)	AVERAGE SMOKE QUANTITY
101	M81381	30 / 28	35 / 12	35 / 7	MODERATE
106	M22759	30 / 9	30 / 20	30 / 13	MODERATE
136	FILOTEX	30 / 15	35 / 9	30 / 24	MODERATE
141	TENSOLITE #3	35 / 14	35 / 21	35 / 17	MODERATE
146	THERMATICS #3	35 / 22	35 / 29	35 / 25	LITTLE
156	NEMA #3	30 / 15	35 / 7	30 / 21	MODERATE

TABLE 5.21 - TIME/CURRENT TO SMOKE TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CURRENT/TIME (AMP/SECOND)	MAXIMUM CURRENT/TIME (AMP/SECOND)	AVERAGE CURRENT/TIME (AMP/SECOND)	AVERAGE SMOKE QUANTITY
102	M81381	30 / 18	35 / 14	35 / 5	MODERATE
107	M22759	25 / 25	30 / 16	30 / 6	MODERATE
137	FILOTEX	30 / 9	35 / 9	30 / 27	MODERATE
142	TENSOLITE #3	35 / 9	35 / 20	35 / 13	MODERATE
147	THERMATICS #3	35 / 4	35 / 17	35 / 9	LITTLE
157	NEMA #3	30 / 7	30 / 15	30 / 11	MODERATE

TABLE 5.22 - TIME/CURRENT TO SMOKE TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CURRENT/TIME (AMP/SECOND)	MAXIMUM CURRENT/TIME (AMP/SECOND)	AVERAGE CURRENT/TIME (AMP/SECOND)	AVERAGE SMOKE QUANTITY
103	M81381	20 / 3	20 / 7	20 / 5	ABUNDANT
108	M22759	20 / 2	20 / 9	20 / 5	ABUNDANT
138	FILOTEX	20 / 4	20 / 10	20 / 7	MODERATE
143	TENSOLITE #3	20 / 3	20 / 17	20 / 12	MODERATE
148	THERMATICS #3	20 / 2	20 / 17	20 / 6	MODERATE
158	NEMA #3	15 / 7	15 / 25	15 / 12	LITTLE

TABLE 5.23 - TIME/CURRENT TO SMOKE TEST RESULTS ON 22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CURRENT/TIME (AMP/SECOND)	MAXIMUM CURRENT/TIME (AMP/SECOND)	AVERAGE CURRENT/TIME (AMP/SECOND)	AVERAGE SMOKE QUANTITY
104	M81381	35 / 11	40 / 5	35 / 21	LITTLE
109	M22759	45 / 29	50 / 9	50 / 5	LITTLE
239	FILOTEX	40 / 25	55 / 30	50 / 9	LITTLE
144	TENSOLITE #3	40 / 13	50 / 6	45 / 13	LITTLE
249	THERMATICS #3	40 / 29	45 / 11	45 / 7	LITTLE
159	NEMA #3	40 / 5	40 / 26	40 / 11	LITTLE

TABLE 5.24 - TIME/CURRENT TO SMOKE TEST RESULTS ON 26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CURRENT/TIME (AMP/SECOND)	MAXIMUM CURRENT/TIME (AMP/SECOND)	AVERAGE CURRENT/TIME (AMP/SECOND)	AVERAGE SMOKE QUANTITY
105	M81381	25 / 5	25 / 12	25 / 7	LITTLE
110	M22759	30 / 7	30 / 13	30 / 10	LITTLE
240	FILOTEX	30 / 4	30 / 8	30 / 6	LITTLE
145	TENSOLITE #3	20 / 28	30 / 11	25 / 26	LITTLE
150	THERMATICS #3	25 / 5	30 / 6	25 / 16	LITTLE
160	NEMA #3	20 / 28	25 / 6	25 / 3	LITTLE

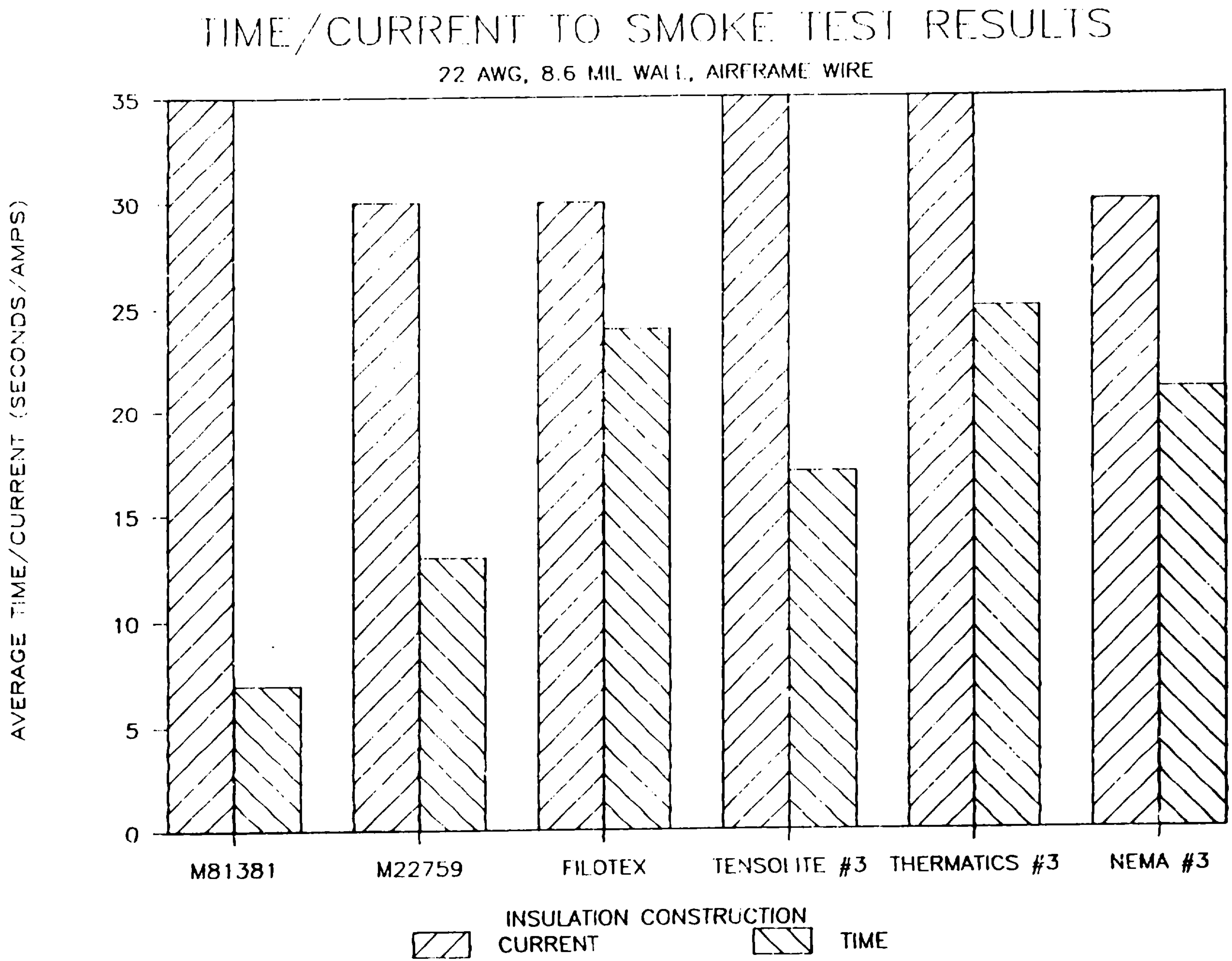


FIGURE 5.18 - TIME/CURRENT TO SMOKE TEST RESULTS, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

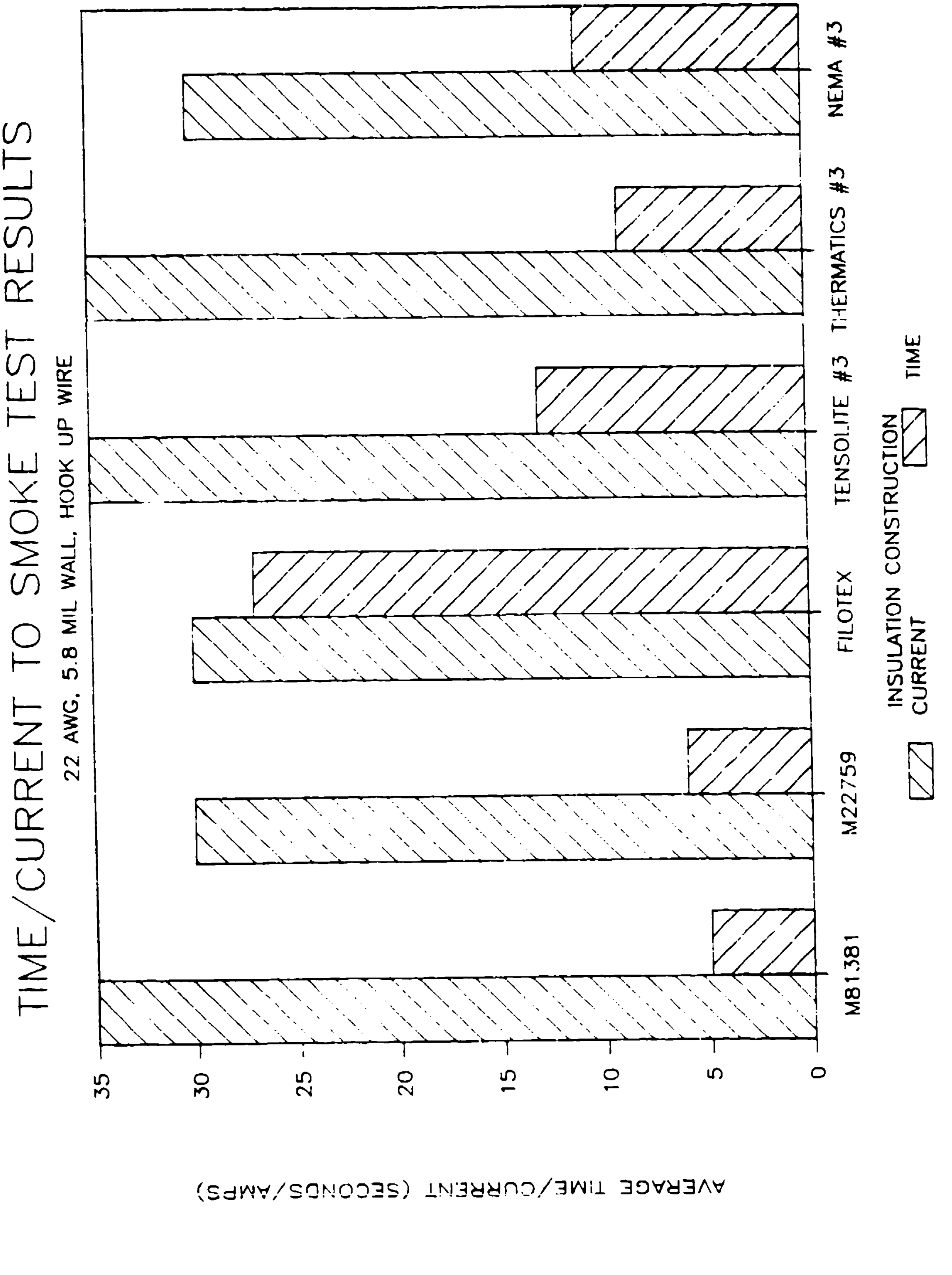


FIGURE 5.19 - TIME/CURRENT TO SMOKE TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

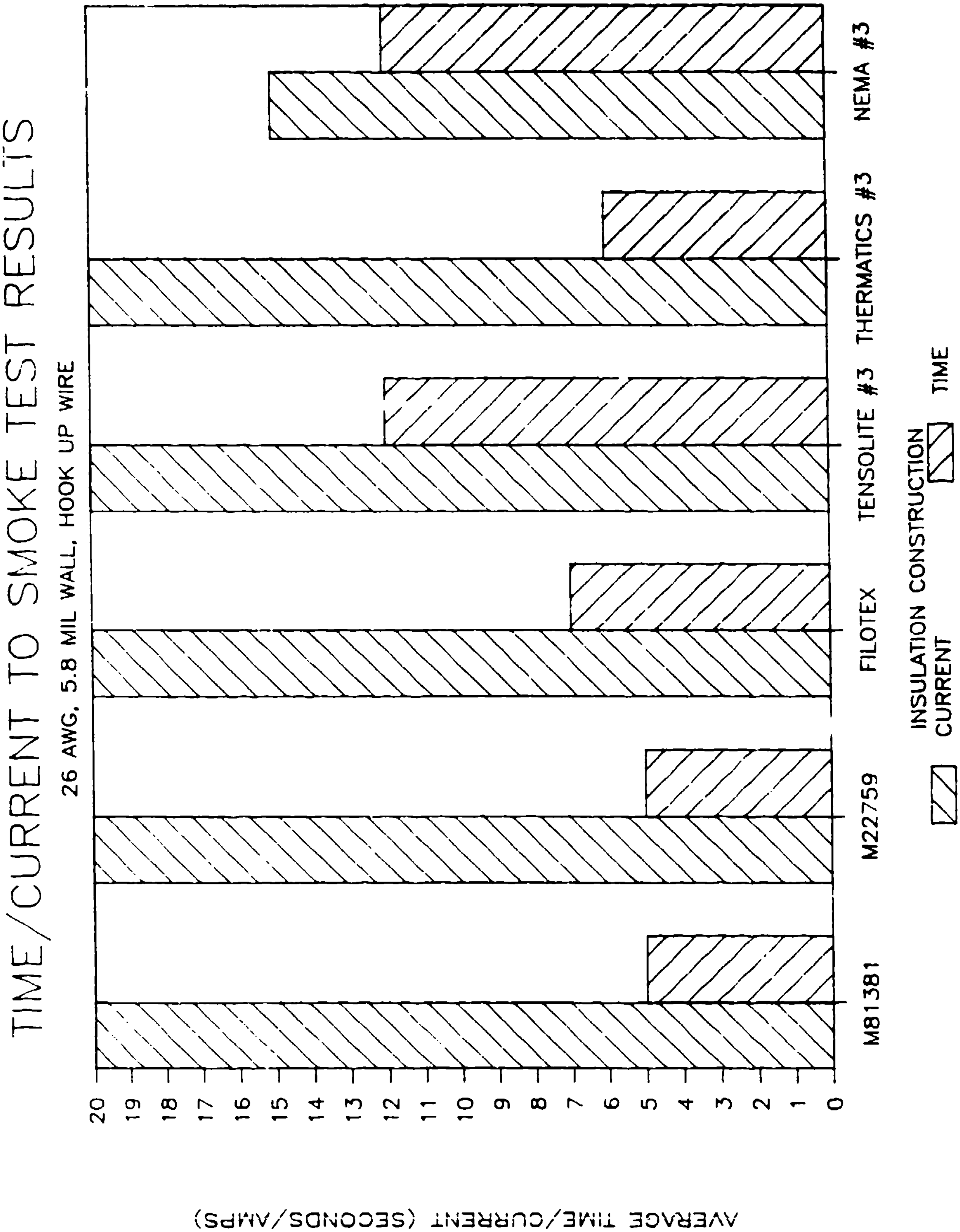


FIGURE 5.20 - TIME/CURRENT TO SMOKE TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

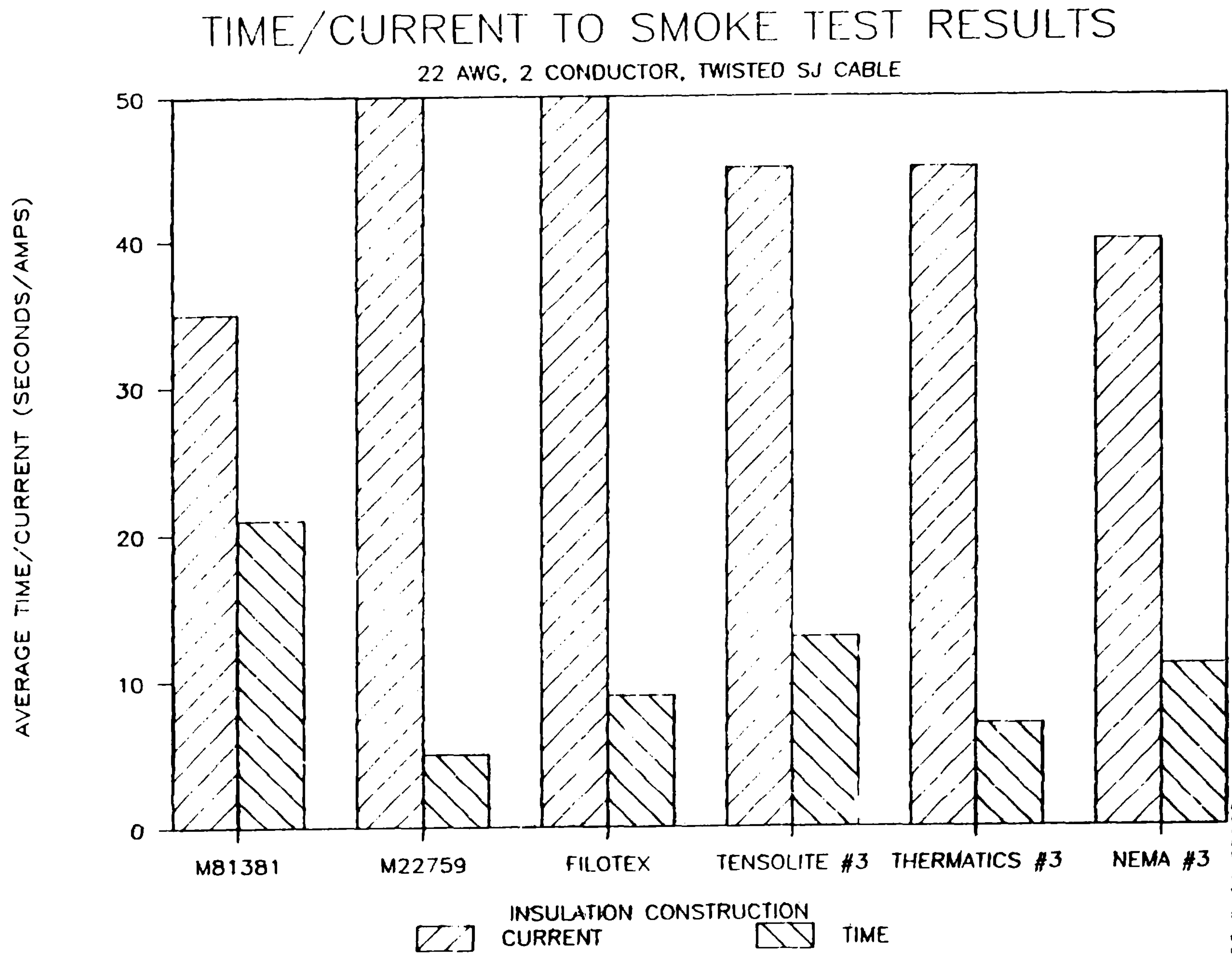


FIGURE 5.21 - TIME/CURRENT TO SMOKE TEST RESULTS, 22AWG, 2 CONDUCTOR, TWISTED SJ CABLE

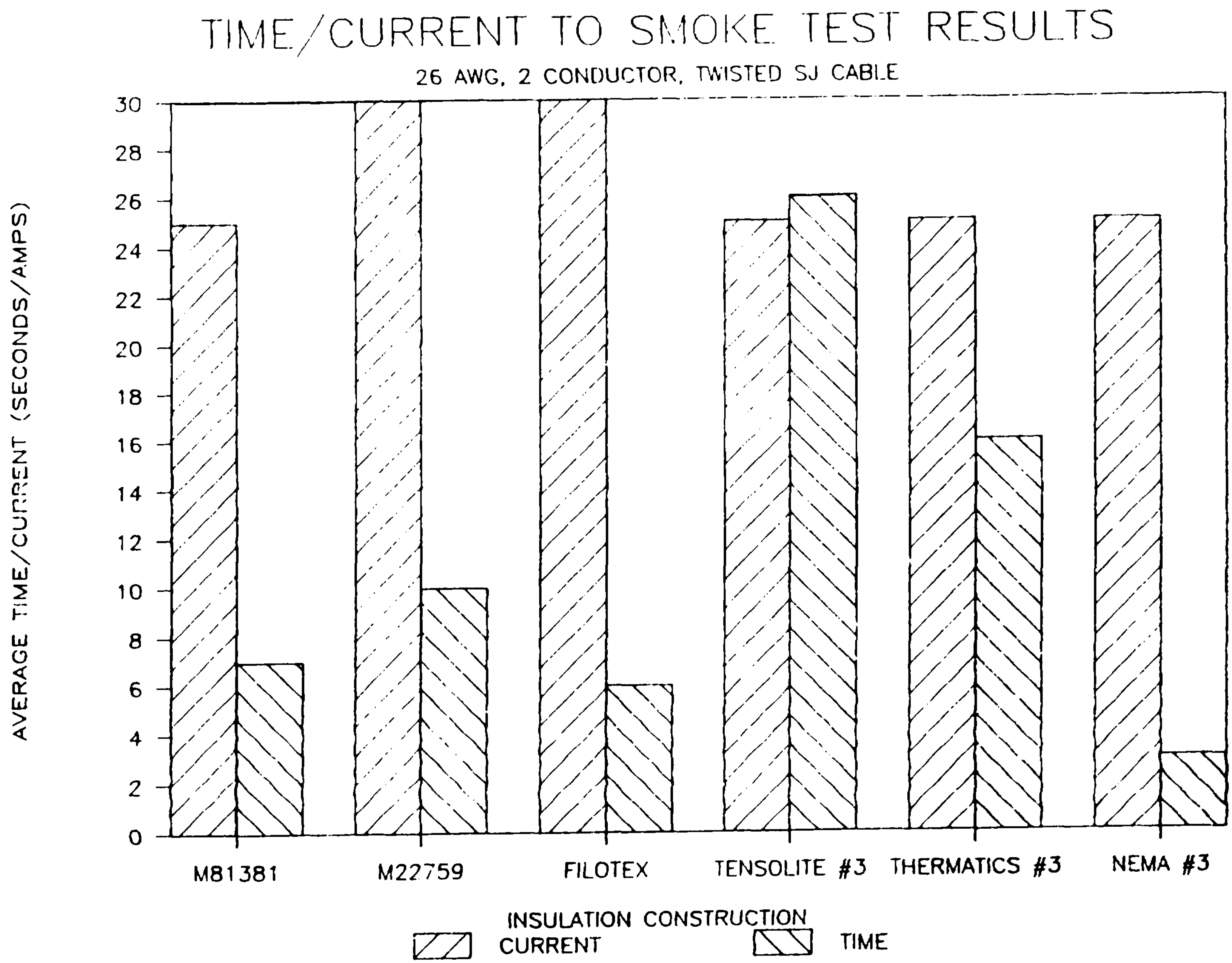


FIGURE 5.22 - TIME/CURRENT TO SMOKE TEST RESULTS, 26AWG, 2 CONDUCTOR, TWISTED SJ CABLE

5.3.5 **WET ARC TRACKING.**

5.3.5.1 Scope: The Wet Arc Tracking Test was used to evaluate the performance of an unconditioned insulated wire sample under wet arc track conditions. This test became a BSI standard as of March 1989.

5.3.5.2 Reference Procedure: The Wet Arc Tracking Test was conducted according to Method 509 of SAE AS4373 with the modification of a maximum of eight hours of electrolytic action.

5.3.5.3 Specimens: One seven wire harness was fabricated from each 22 gauge, 8.6 mil wall, airframe wire sample and one from each 22 gauge, 5.8 mil wall, hook up wire sample. Seven wires were cut to a length of 400 millimeters and cleaned using cheesecloth containing isopropyl alcohol. Two of the seven wires were damaged near the center portion of the wire by cutting a notch 0.5±0.1 millimeters wide around the entire circumference of the wire. The wires were notched by placing two blades of an Ideal Coaxial Cable Cutter back to back in the tool. The blade depth was adjusted for each sample so as not to damage any of the conductors when severing the insulation. The insulation was removed using tweezers. The notches were placed at 200 millimeters and 210 millimeters from one end of each of the two wires in

the specimen.

The harness was fabricated with wires positioned in a six around one configuration with string ties (MIL-T-43435-B, type IV) tied every 30 millimeters. The wire positioning was accomplished by securing the seven wires to two Amphenol receptacles which were mounted in vises. The wires passed through an additional receptacle that ensured proper positioning of the wires when applying the string ties. The two damaged wires were placed adjacent to one another with the cuts horizontally separated by 10±0.5 millimeters. The string ties were positioned 15 millimeters from one notch and 5 millimeters from the other with 10 millimeters separating the two notches. A 10 millimeter section of insulation was removed from the wire ends and spade terminals were crimped onto the conductors to apply power to the harness.

5.3.5.4 Test Equipment: The outer six wires of the harness were connected sequentially to phases A, B, and C, with the center wire connected to neutral. Low power indicator lights were used to show when a wire became open circuit. Each powered line in the harness had a MS3320, 7.5 amp, thermal circuit breaker. The circuit breakers of each phase received their power through a 0.5 ohm resistor which connected the harness to the power source. The power supply used was three phase, 115 volt,

400 Hertz, 100 amps per phase, laboratory power. Indicating lights were used to monitor if the particular wire was powered or became open circuit. The lamps were connected across each powered line to neutral. A switch was installed to change the neutral path from the harness neutral to the neutral at the power receptacle. This provided the ability to monitor the harness neutral wire in case it became open circuit. The entire set-up was placed in a wooden enclosure with a clear plastic front panel to provide a safe viewing environment to monitor the test. The enclosure was vented with a blower operating at the lowest possible speed to minimize interference with the test.

A 100 milliliter pipette, having a tube diameter of 1.0±0.1 millimeters and capable of delivering a drop sized to 20±3 millimeters at a rate of two drops per minute (±10 seconds), was positioned over the harness. The pipette was placed two to four millimeters above the harness and one to two millimeters from the first notch, 15 millimeters away from the string tie. The solution flowed from the pipette, over the fist notch (15 millimeters from the string tie), over the second notch (five millimeters from the string tie), and out through a hole in the Teflon base plate. The area on the Teflon support plate under the harness was hollowed out and connected to a drain to prevent flooding. The harness was secured to a Teflon base plate with the damaged wires

facing the pipette. Three mil Teflon tape was used to secure the harness to the Teflon base plate. The Teflon base plate was positioned at a 10° angle from the horizontal and suspended in free air.

The electrolyte fluid consisted of 1% Ammonium Chloride (by mass) and 0.02 ± 0.002% (by mass) of Iso-octylphenoxypolyethoxyethanol, a non ionic wetting agent, diluted in distilled water.

A Beckman Megohmmeter (MD 078996) was used to conduct the insulation resistance measurements between powered conductors.

An NJE Corporation Model CR-36-30, 0-36 volt, 0-30 amp, dc power supply (MD 046001) was used to conduct the circuit breaker integrity test. The circuit breakers were connected in series with a two ohm resistor and connected to the power supply. The power supply current regulator was used to limit the current to 15 amps to each individual circuit breaker.

Photographs of the test setup and equipment are presented in Figures 5.25 through 5.27.

5.3.5.5 Test Procedure: The test was performed at room ambient in a vented chamber. Electrolyte flow was initiated and power was applied to the harness. Care was taken to ensure that the electrolyte solution was flowing over the damaged sections and into the wire harness and not rolling off the sides.

The test ran continuously on each harness for eight hours unless an active failure occurred. The electrolyte solution was maintained near the 80 milliliter point on the pipette where the drip rate of two drops per minute was most consistent. The test was observed for one of the following:

(A.) Active Failure: An active failure was defined as a disruptive arc such that an open circuit of the conductor, tripping of the circuit breaker, or arc propagation results. Following an active failure, the electrolyte flow was stopped and power was maintained to the harness for a period of 30±5 minutes. After that 30 minute time period, power was removed for 1.5±0.5 minutes and the circuit breakers were reset. Power was then reapplied for a period of 15 minutes. There was no additional reset of circuit breakers. The circuit breakers that tripped initially, reset circuit breakers that tripped, and time to failure were recorded and the test was terminated.

(B.) Passive Failures: A passive failure will not trip circuit breakers but will usually involve the progressive erosion of the conductors until an open circuit occurs on one or both of the damaged wires. A passive failure was detected by monitoring the indicating lights on each powered line.

The following day after the eight hour electrolytic test, an Insulation Resistance Test was conducted between all conductors at 500 volts dc. The specimen remained in the test setup overnight, and the Insulation Resistance Test was conducted at the start of the next morning. The harness was disconnected from the terminal strip and one wire was attached to the positive lead of the Beckman Megohmmeter. The remaining six wires were shorted together and attached to the ground terminal of the meter. The resistance reading was measured after the 500 volt dc potential was applied for one minute. The test was repeated on all seven wires.

The test results recorded the time for circuit interruption (active or passive failure), circuit breakers which tripped initially and after being reset, Insulation Resistance Test results, and description of the damage to the insulation including the length of charring. Photographs of the damaged portions of the harnesses were obtained.

The circuit breakers used in the test were given a 200% dc overload test to verify their operation after each wet arc tracking test and before being used on the next test. All breakers were verified to trip between 1.5 and 40 seconds as specified before being incorporated into the test circuit.

5.3.5.6 Test Results: The average length of harness damage was determined from the length of burnt insulation and additional charring of the specimen.

The status of the circuit breakers, average length of harness damage, time to active failure, time to passive failure, the number of wires involved in the passive failure, and the results of the Insulation Resistance Test are presented in Tables 5.25 through 5.30 with graphical representation of the data presented in Figures 5.23 through 5.24.

Photographs of the damaged sections of the test harnesses are presented in Exhibit A of Volume I of this report.

TABLE 5.25 - WET ARC TRACKING CIRCUIT BREAKER TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

		INIT. C/B STATUS						C/B RESET STATUS					
SPOOL REF.	INSULATION CONSTRUCTION	#1 ØA	#2 ØB	#3 ØC	#4 ØA	#5 ØB	#6 ØC	#1 ØA	#2 ØB	#3 ØC	#4 ØA	#5 ØB	#6 ØC
101	M81381	T	T	C	C	T	T	T	T	T	T	T	T
106	M22759	C	C	C	C	C	C	C	C	C	C	C	C
136	FILOTEX	C	C	C	C	C	C	C	C	C	C	C	C
141	TENSOLITE #3	C	C	C	C	C	C	C	C	C	C	C	C
146	THERMATICS #3	C	C	C	C	C	C	C	C	C	C	C	C
156	NEMA #3	C	C	C	C	C	C	C	C	C	C	C	C

T = CIRCUIT BREAKER TRIPPED.
C = CIRCUIT BREAKER REMAINED CLOSED.

TABLE 5.26 - WET ARC TRACKING HARNESS TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE LENGTH OF CHARRED INSULATION (INCHES)	TIME TO ACTIVE FAILURE (MINUTES)	TIME TO PASSIVE FAILURE (MINUTES)	NUMBER OF WIRES INVOLVED IN PASSIVE FAILURES
101	M81381	3.00	4	-----	------
106	M22759	0.75	0	262	5
136	FILOTEX	0.63	0	154	1
141	TENSOLITE #3	0.75	0	0	0
146	THERMATICS #3	0.00	0	0	0
156	NEMA #3	0.75	0	0	0

TABLE 5.27 - WET ARC TRACKING INSULATION RESISTANCE TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	#1 ØA	#2 ØB	#3 ØC	#4 ØA	#5 ØB	#6 ØC	#7 N
101	M81381	S	S	S	S	S	S	S
106	M22759	O	O	O	O	S	S	S
136	FILOTEX	O	O	O	O	O	O	O
141	TENSOLITE #3	O	O	O	O	O	O	O
146	THERMATICS #3	O	O	O	O	O	O	O
156	NEMA #3	O	O	O	O	O	O	O

S = INSULATION RESISTANCE WAS LESS THAN ONE MEGOHM.
O = INSULATION RESISTANCE WAS GREATER THAN ONE MEGOHM.

TABLE 5.28 - WET ARC TRACKING CIRCUIT BREAKER TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INIT. C/B STATUS						C/B RESET STATUS					
		#1 ØA	#2 ØB	#3 ØC	#4 ØA	#5 ØB	#6 ØC	#1 ØA	#2 ØB	#3 ØC	#4 ØA	#5 ØB	#6 ØC
102	M81381	T	T	T	C	T	T	T	T	T	T	T	T
107	M22759	C	C	C	C	C	C	C	C	C	C	C	C
137	FILOTEX	C	C	C	C	C	C	C	C	C	C	C	C
142	TENSOLITE #3	C	C	C	C	C	C	C	C	C	C	C	C
147	THERMATICS #3	C	C	C	C	C	C	C	C	C	C	C	C
157	NEMA #3	C	T	C	T	C	T	C	T	C	C	C	C

T = CIRCUIT BREAKER TRIPPED.
C = CIRCUIT BREAKER REMAINED CLOSED.

TABLE 5.29 - WET ARC TRACKING HARNESS TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE LENGTH OF CHARRED INSULATION (INCHES)	TIME TO ACTIVE FAILURE (MINUTES)	TIME TO PASSIVE FAILURE (MINUTES)	NUMBER OF WIRES INVOLVED IN PASSIVE FAILURES
102	M81381	6.00	8	-----	------
107	M22759	1.00	0	462	4
137	FILOTEX	0.63	0	0	0
142	TENSOLITE #3	0.19	0	0	0
147	THERMATICS #3	1.25	0	0	0
157	NEMA #3	2.50	445	-----	------

TABLE 5.30 - WET ARC TRACKING INSULATION RESISTANCE TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	#1 ØA	#2 ØB	#3 ØC	#4 ØA	#5 ØB	#6 ØC	#7 N
102	M81381	S	S	S	S	S	S	S
107	M22759	O	O	O	O	O	O	O
137	FILOTEX	O	O	O	O	O	O	O
142	TENSOLITE #3	O	O	O	O	O	O	O
147	THERMATICS #3	O	O	O	O	O	O	O
157	NEMA #3	O	O	O	O	O	O	O

S = INSULATION RESISTANCE WAS LESS THAN ONE MEGOHM.
O = INSULATION RESISTANCE WAS GREATER THAN ONE MEGOHM.

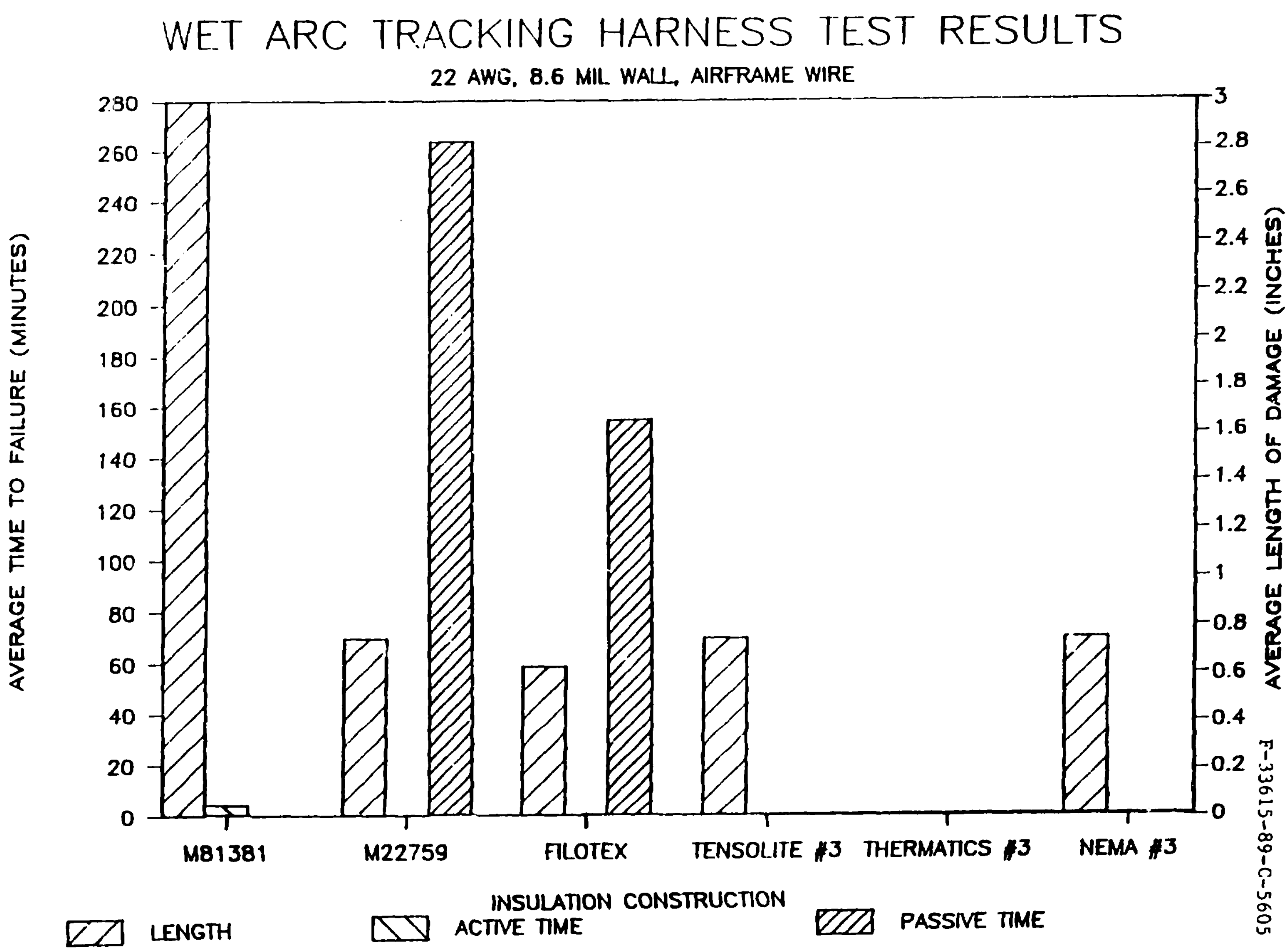


FIGURE 5.23 - WET ARC TRACKING HARNESS TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

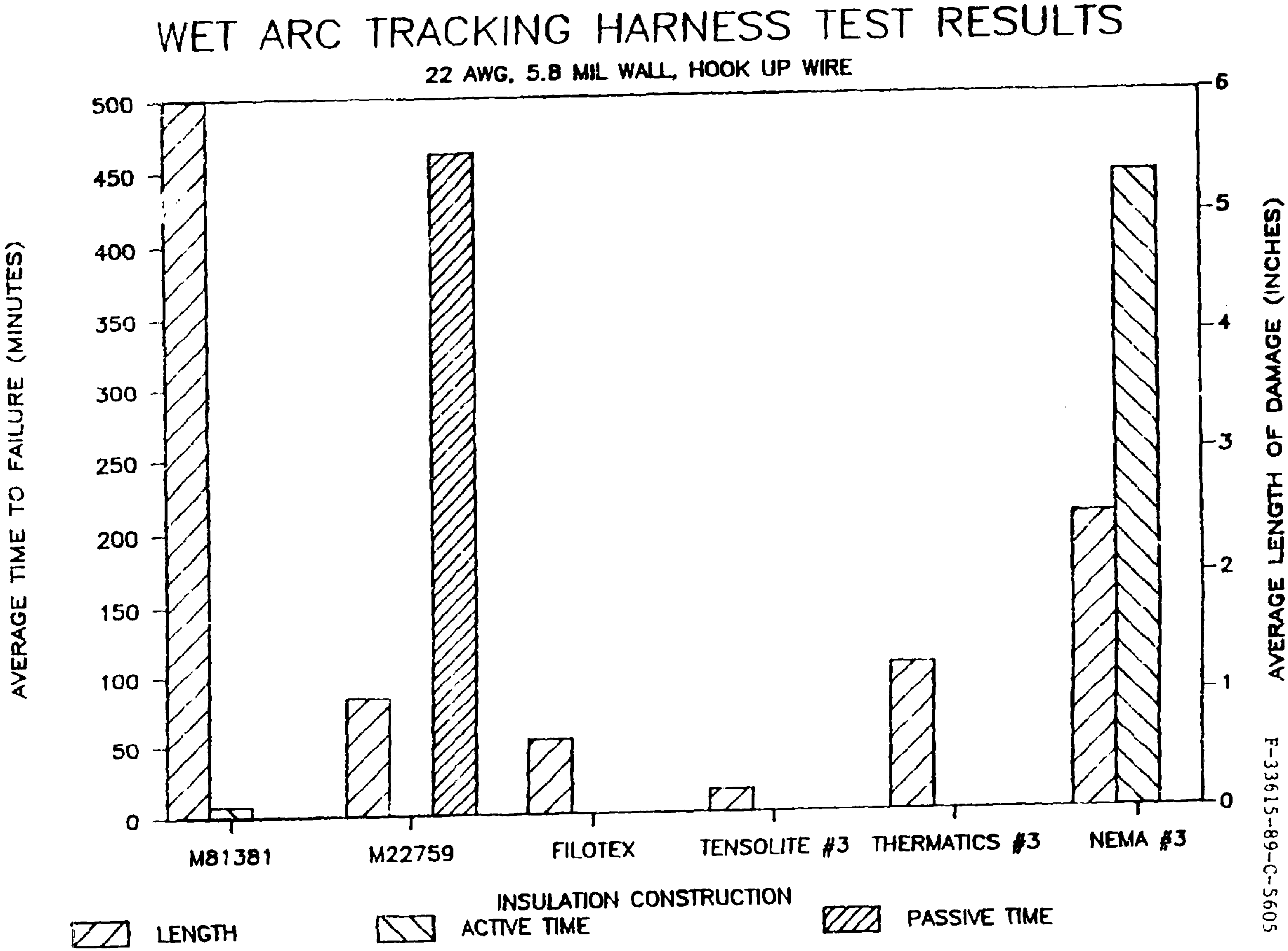


FIGURE 5.24 - WET ARC TRACKING HARNESS TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

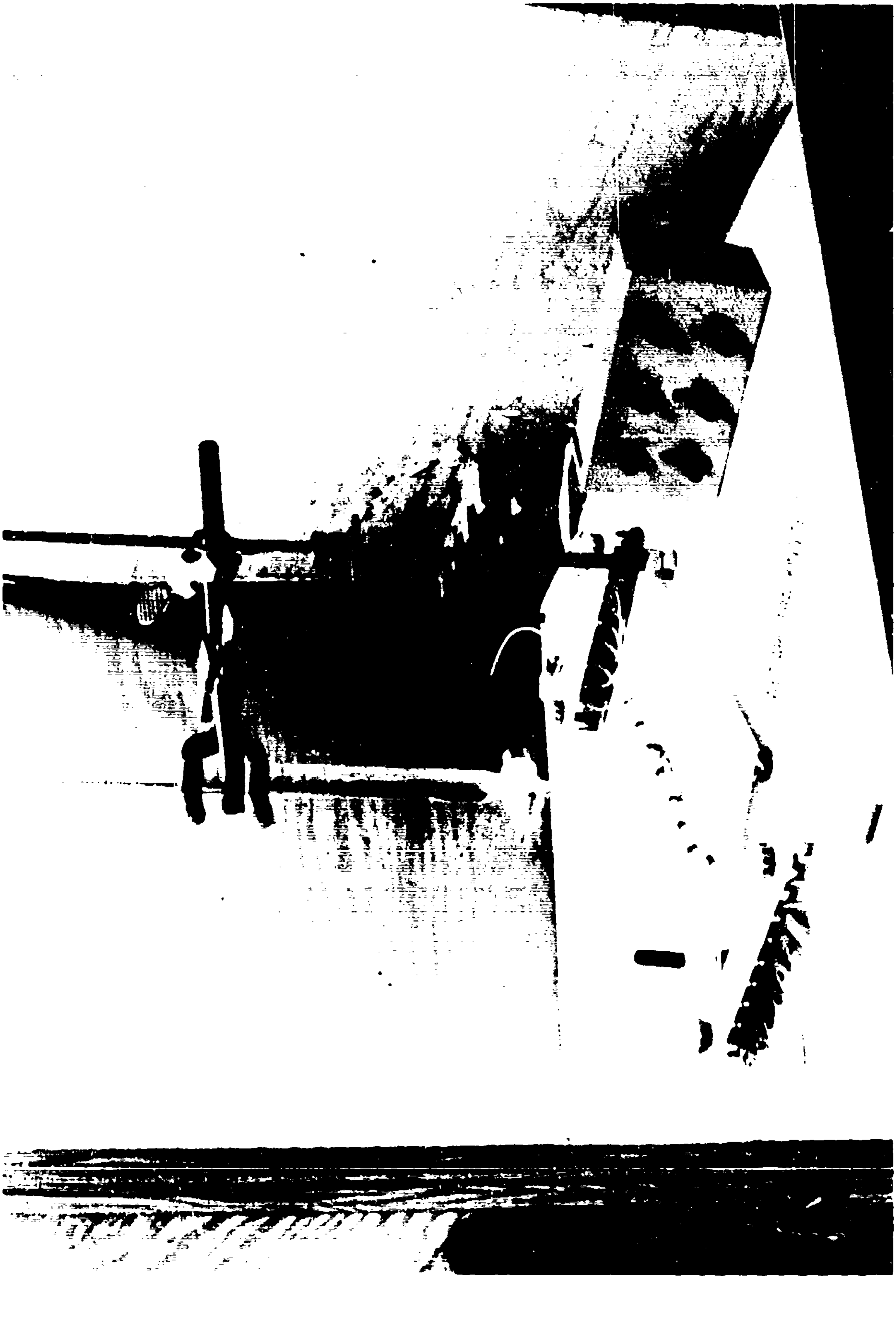


FIGURE 5.25 - WET ARC TRACKING HARNESS TEST SETUP

FIGURE 5.26 - WET ARC TRACKING HARNESS TEST SETUP

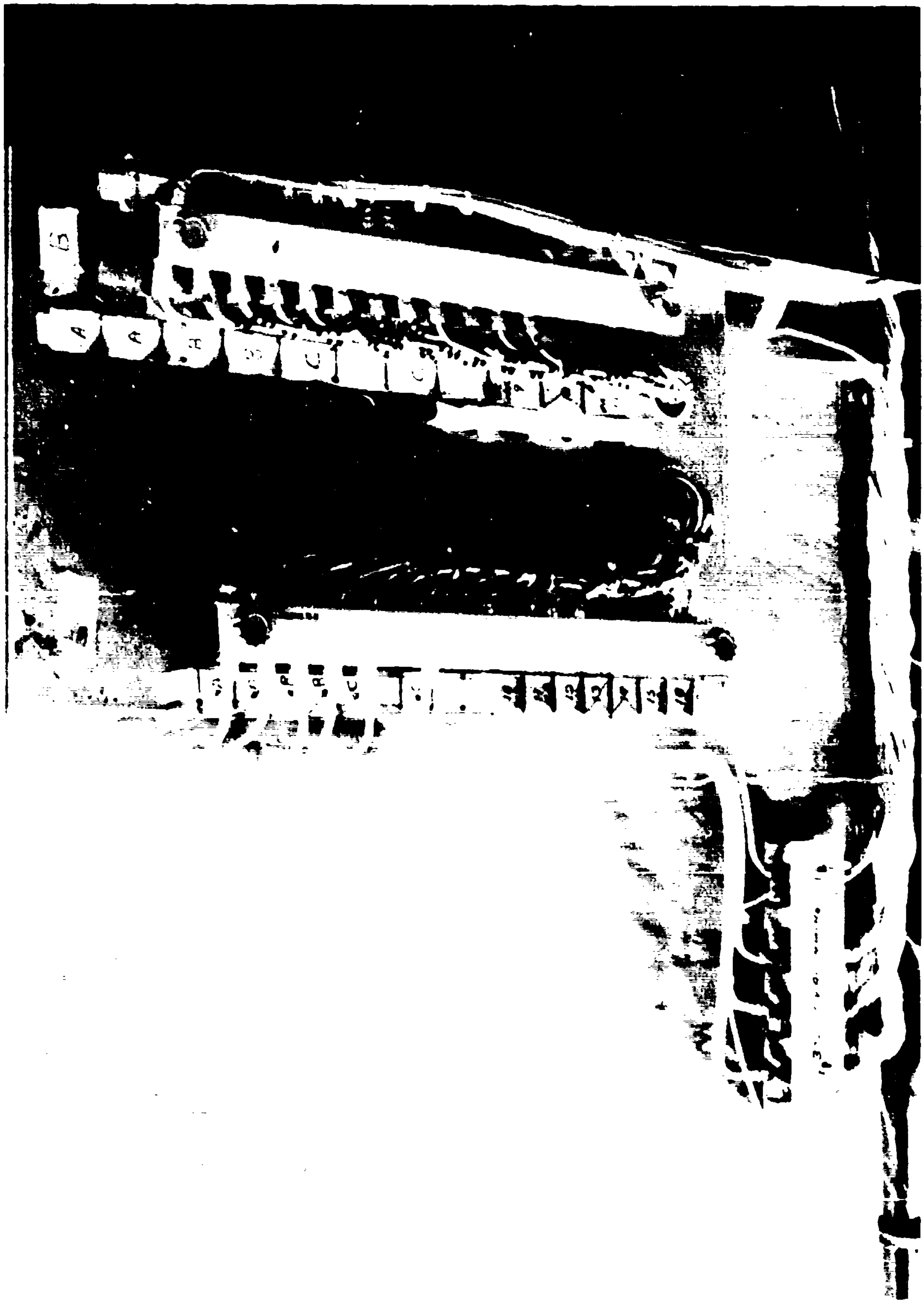


FIGURE 5.27 - WET ARC TRACKING HARNESS TEST CIRCUIT BREAKER PANEL

5.3.6 **WIRE FUSING TIME.**

5.3.6.1 Scope: The Wire Fusing Time Test was used to determine the time for an insulated wire sample to interrupt current during overcurrent conditions.

5.3.6.2 Reference Procedure: The Wire Fusing Time Test was conducted according to Method 511 of SAE AS4373, which references MIL-W-5088, Figure 3, for the free air rated currents.

5.3.6.3 Specimens: Unconditioned specimens were constructed for 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Six specimens of each sample were cut to a length of twelve inches with a half inch of insulation removed from both ends.

5.3.6.4 Test Equipment: A Hewlett-Packard 6456B (MD 089444) 100 amp dc power supply was used as the constant current source for the test. The test set up consisted of the dc power supply, the specimen, and a 100 amp-100 millivolt Weston shunt (MD 178620) connected in series. The current duration and amplitude were determined by monitoring the voltage drop across the shunt using a Hewlett-Packard 3465A Digital Multimeter (MD 653496) and a stopwatch. The test was initiated by closing a

Cutler-Hammer 200 amp relay and monitoring a stopwatch to determine the fusing time. The test was set up in a vented chamber due to specimen outgassing. The exhaust fan was set on a low setting during the test to prevent external cooling and its speed was increased after the test was completed.

Photographs of the test setup is presented in Figures 5.29 through 5.30.

5.3.6.5 Test Procedure: The specimen was attached to a terminal block which was suspended horizontally by wooden blocks. The dc constant current supply was set to 2.5 times the free air rated current of the specimen. The free air rated current of 22 gauge silver plated copper is 18 amps, while that for 26 gauge silver plated alloy is 9 amps. The test currents used were 45 amps for 22 gauge silver plated copper and 22.5 amps for 26 gauge silver plated alloy. The current was applied by closing the relay and the time for the current interruption was recorded. The test was terminated after five minutes if no current interruption occurred.

5.3.6.6 Test Results: The average time to interrupt 2.5 times the free air rated current of the specimen is presented in Tables 5.31 through 5.33 with graphical representation or the data presented in Figure 5.28.

TABLE 5.31 - WIRE FUSING TIME TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE TIME TO INTERRUPT 45 AMPS
101	M81381	22.30
106	M22759	16.25
136	FILOTEX	15.67
141	TENSOLITE #3	24.62
146	THERMATICS #3	19.90
156	NEMA #3	17.26

TABLE 5.32 - WIRE FUSING TIME TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE TIME TO INTERRUPT 45 AMPS
102	M81381	19.25
107	M22759	12.79
137	FILOTEX	12.69
142	TENSOLITE #3	20.75
147	THERMATICS #3	16.28
157	NEMA #3	15.22

TABLE 5.33 - WIRE FUSING TIME TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE TIME TO INTERRUPT 22.5 AMPS
103	M81381	23.81
108	M22759	8.80
138	FILOTEX	13.31
143	TENSOLITE #3	13.85
148	THERMATICS #3	9.67
158	NEMA #3	7.94

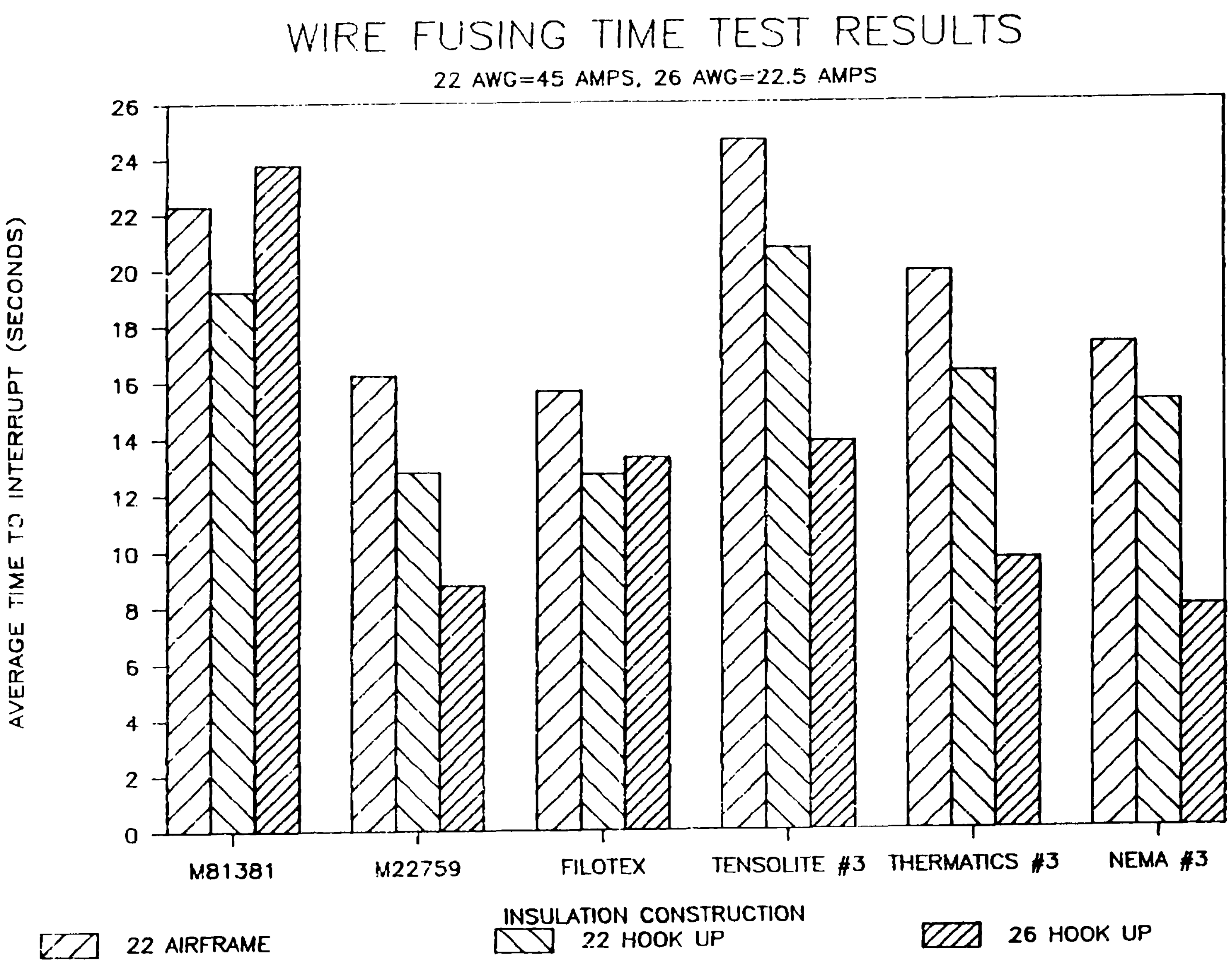


FIGURE 5.28 - WIRE FUSING TIME TEST RESULTS, 22AWG=45 AMPS, 26 AWG=22.5 AMPS

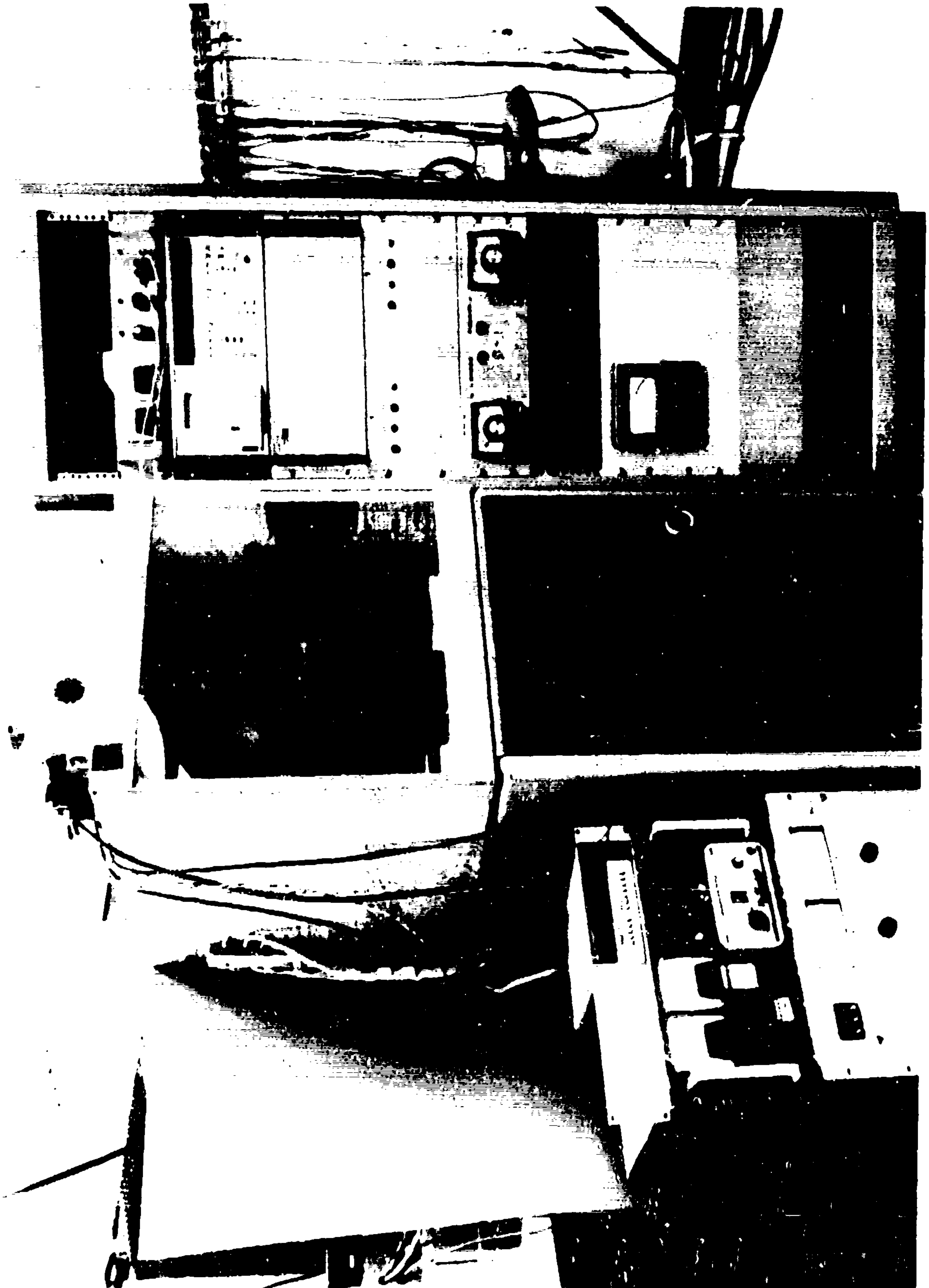


FIGURE 5.29 - WIRE FUSING TIME TEST SETUP

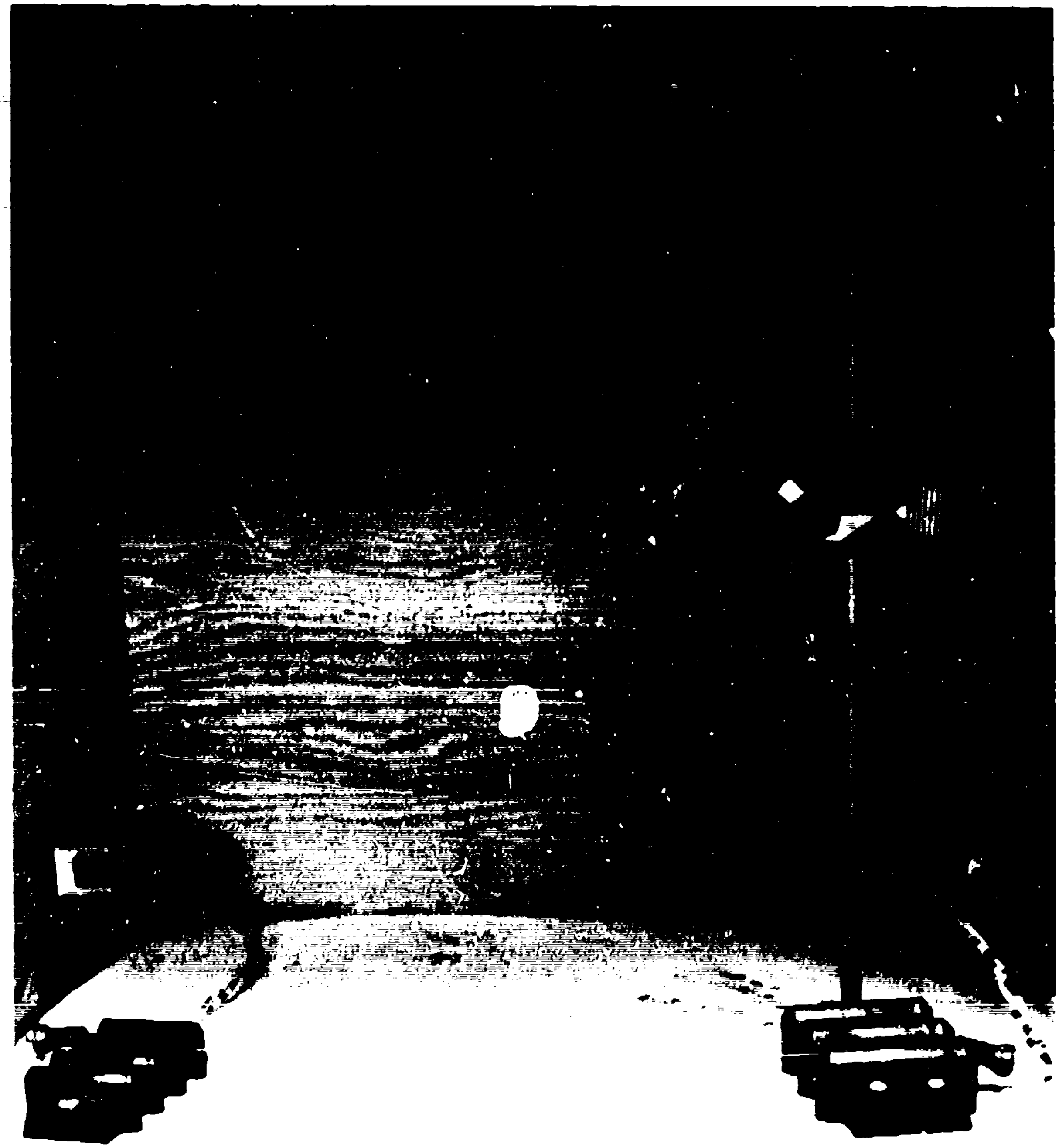


FIGURE 5.30 - WIRE FUSING TIME TEST SETUP

5.4 ENVIRONMENTAL TESTS

5.4.1 FORCED HYDROLYSIS.

5.4.1.1 Scope: The Forced Hydrolysis Test was used to evaluate the hydrolytic stability of the wire insulations.

5.4.1.2 Reference Procedure: The Forced Hydrolysis Test was performed in accordance with Method 602 of SAE AS4373 with the modification that the thermal conditioning consisted of eight hours in a forced draft air oven at 200°C (398°F). The Voltage Withstand Test was performed according to Method 510 of SAE AS4373.

5.4.1.3 Specimens: Specimens were constructed from 22 and 26 gauge, 5.8 mil wall, hook up wire. Twelve specimens were cut to a length of 30 inches for each wire sample. A quarter inch of insulation removed from both ends of the specimen and #10 ring terminals were crimped onto the conductor.

The specimens were wrapped around a solid PTFE (polytetrafluoroethylene) rod approximately six times the diameter of the wire for ten adjacent turns. A 0.5 pound weight was applied to the specimen during wrapping to apply a constant value for tension. The 22 gauge specimens used a 0.25 inch diameter rod while the 26

gauge specimens used a 0.19 inch diameter rod. The specimens were secured to the mandrels by use of self-locking Nylon Ty-Rap ties.

One set of six specimens, after being wrapped around the mandrels, underwent thermal conditioning of 8 hours at 200°C (392°F). The remaining six specimens were unconditioned.

5.4.1.4 Test Equipment: The Forced Hydrolysis Test Chamber consisted of a 33.3 gallon vat with a Love Temperature Controller Model 2565 (MD B191939) controlling the Dayton 1000 watt heater. The solution's temperature was monitored by use of a Fluke Datalogger 2240B (MD 79987) with type J thermocouples. The Love Temperature Controller was used to maintain the 5% salt solution at 70°C (158°F). A 0.025 horsepower March Mfg. water pump (Model AC-2CP-MD) was used for fluid circulation to the heater.

A Slaughter 103/105 Dielectric Tester (MD 078995) was used to conduct the Voltage Withstand Test. The voltage was monitored by a Fluke 8050A Digital Multimeter (MD 011821) through a Fluke 80K-6 High Voltage Probe (MD 189698).

Photographs of the test setup and equipment are presented in Figures 5.33 through 5.36.

5.4.1.5 Test Procedure: The mandrels and specimens were placed in a Teflon holding fixture and immersed in a 5% salt solution at 70°C (158°F) for 720 hours. A minimum of two inches of the terminated ends of the specimens was suspended above the surface of the solution. At the completion of the immersion, the specimens were removed from the solution and the insulation was examined for anomalies while still on the mandrels. At completion of the examination, the specimens were subjected to a Voltage Withstand Test.

The Voltage Withstand test was performed according to Method 510 of SAE AS4373. The test consisted of immersing the specimens and mandrels in a 5% salt solution with 0.1% wetting agent (Aerosol OT) added for a four hour soak period. After the completion of the soak period, a potential of 2500 volts at 60 Hertz was applied to the specimen for a period of one minute unless a failure occurred. The potential was applied to the specimens at a rate of 500 volts per second until the test voltage was achieved. A Voltage Withstand failure was defined as observations of arcing on the specimen or a leakage current greater than 5 milliamps.

5.4.1.6 Test Results: The insulation inspection detected radial cracks at the coiled portions of the specimens. These specimens were identified as failures. The results of the insulation inspection, the Voltage Withstand Test,

and the average leakage current of the specimens that passed the Voltage Withstand Test are presented in Tables 5.34 through 5.37 with graphical representation of the data presented in Figures 5.31 through 5.32.

Photographs of the observed cracks on the specimens are presented in the Addendum.

TABLE 5.34 - FORCED HYDROLYSIS TEST RESULTS ON UNCONDITIONED 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

		UNCONDITIONED SPECIMENS		
SPOOL REF.	INSULATION CONSTRUCTION	INSULATION INSPECTION (P / F)	VOLTAGE WITHSTAND RESULTS (P / F)	AVERAGE LEAKAGE CURRENT (MICRO-AMP)
102	M81381	0 / 6	0 / 6	-------
107	M22759	6 / 0	6 / 0	200
137	FILOTEX	0 / 6	0 / 6	-------
142	TENSOLITE #3	6 / 0	6 / 0	158
147	THERMATICS #3	0 / 6	0 / 6	-------
157	NEMA #3	6 / 0	6 / 0	308

TABLE 5.35 - FORCED HYDROLYSIS TEST RESULTS ON CONDITIONED 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

		CONDITIONED SPECIMENS (8 HOURS AT 200°C)		
SPOOL REF.	INSULATION CONSTRUCTION	INSULATION INSPECTION (P / F)	VOLTAGE WITHSTAND RESULTS (P / F)	AVERAGE LEAKAGE CURRENT (MICRO-AMP)
102	M81381	6 / 0	5 / 1	370
107	M22759	6 / 0	6 / 0	192
137	FILOTEX	6 / 0	0 / 6	-------
142	TENSOLITE #3	6 / 0	6 / 0	150
147	THERMATICS #3	6 / 0	4 / 2	555
157	NEMA #3	6 / 0	6 / 0	183

TABLE 5.36 - FORCED HYDROLYSIS TEST RESULTS ON UNCONDITIONED 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

		UNCONDITIONED SPECIMENS		
SPOOL REF.	INSULATION CONSTRUCTION	INSULATION INSPECTION (P / F)	VOLTAGE WITHSTAND RESULTS (P / F)	AVERAGE LEAKAGE CURRENT (MICRO-AMP)
102	M81381	0 / 6	0 / 6	-------
107	M22759	6 / 0	6 / 0	125
137	FILOTEX	0 / 6	0 / 6	-------
142	TENSOLITE #3	6 / 0	6 / 0	83
147	THERMATICS #3	6 / 0	0 / 6	-------
157	NEMA #3	6 / 0	6 / 0	150

TABLE 5.37 - FORCED HYDROLYSIS TEST RESULTS ON CONDITIONED 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

		CONDITIONED SPECIMENS (8 HOURS AT 200°C)		
SPOOL REF.	INSULATION CONSTRUCTION	INSULATION INSPECTION (P / F)	VOLTAGE WITHSTAND RESULTS (P / F)	AVERAGE LEAKAGE CURRENT (MICRO-AMP)
102	M81381	6 / 0	6 / 0	217
107	M22759	6 / 0	6 / 0	125
137	FILOTEX	6 / 0	6 / 0	230
142	TENSOLITE #3	6 / 0	6 / 0	100
147	THERMATICS #3	6 / 0	0 / 6	-------
157	NEMA #3	6 / 0	6 / 0	167

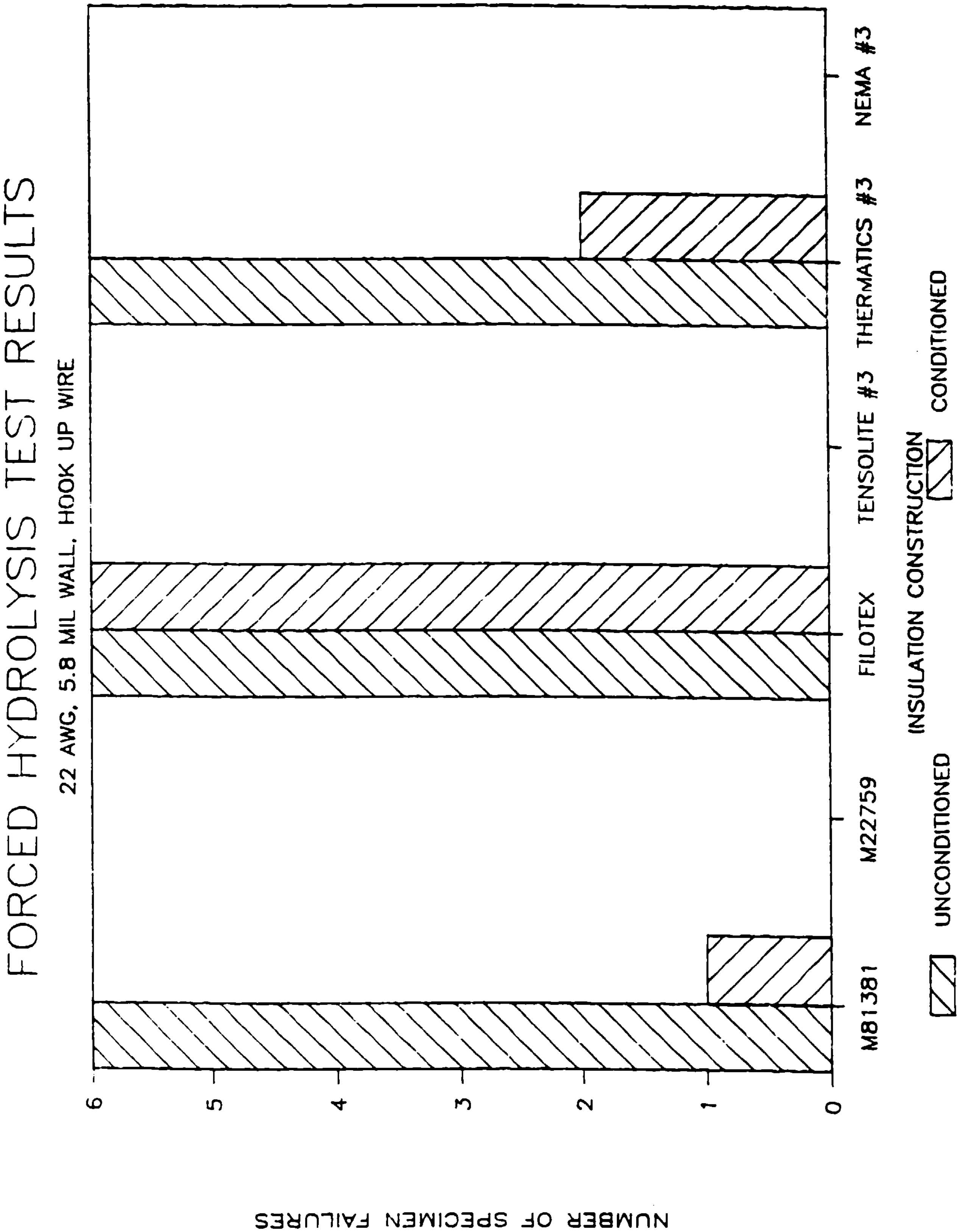


FIGURE 5.31 - FORCED HYDROLYSIS TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

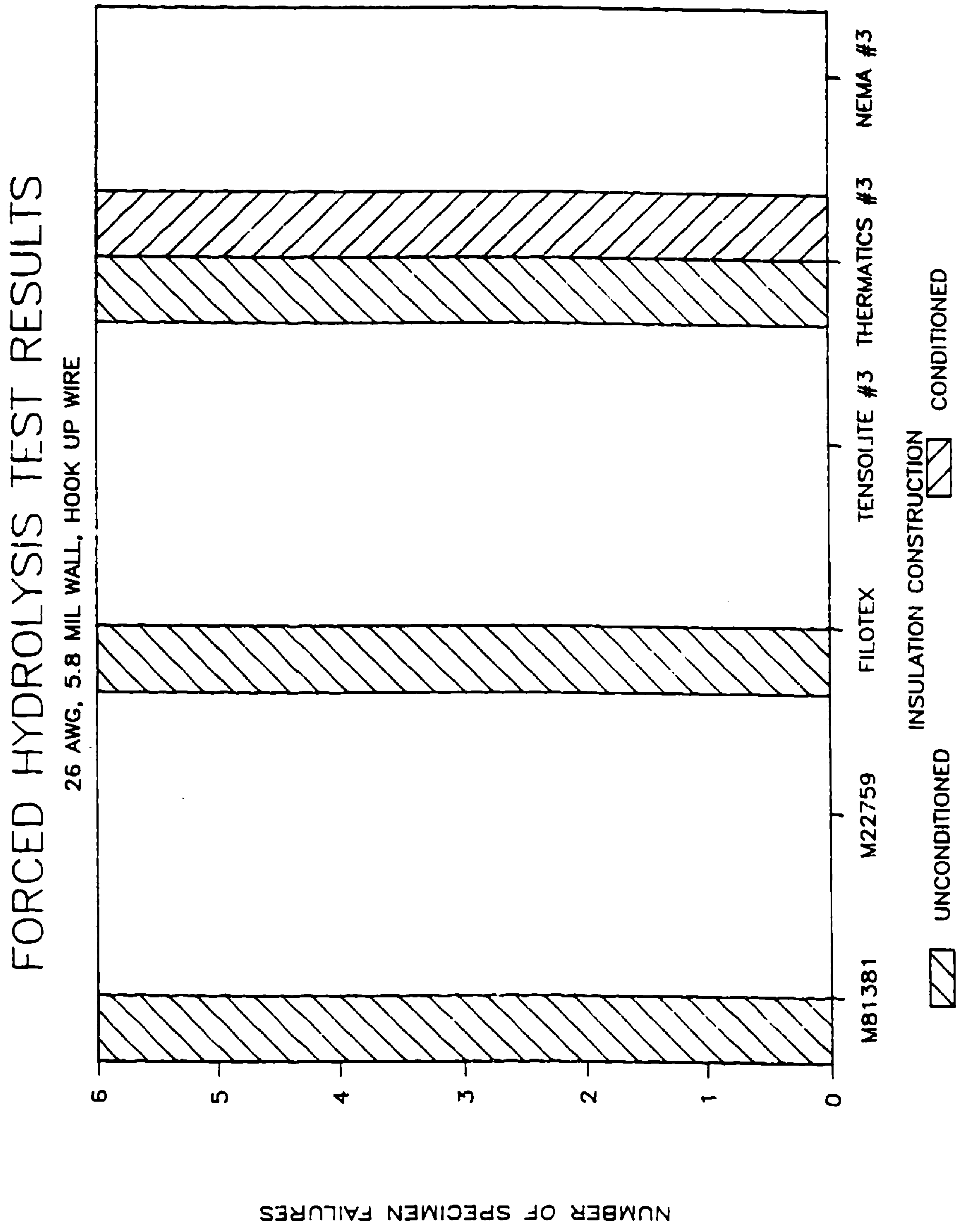


FIGURE 5.32 - FORCED HYDROLYSIS TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

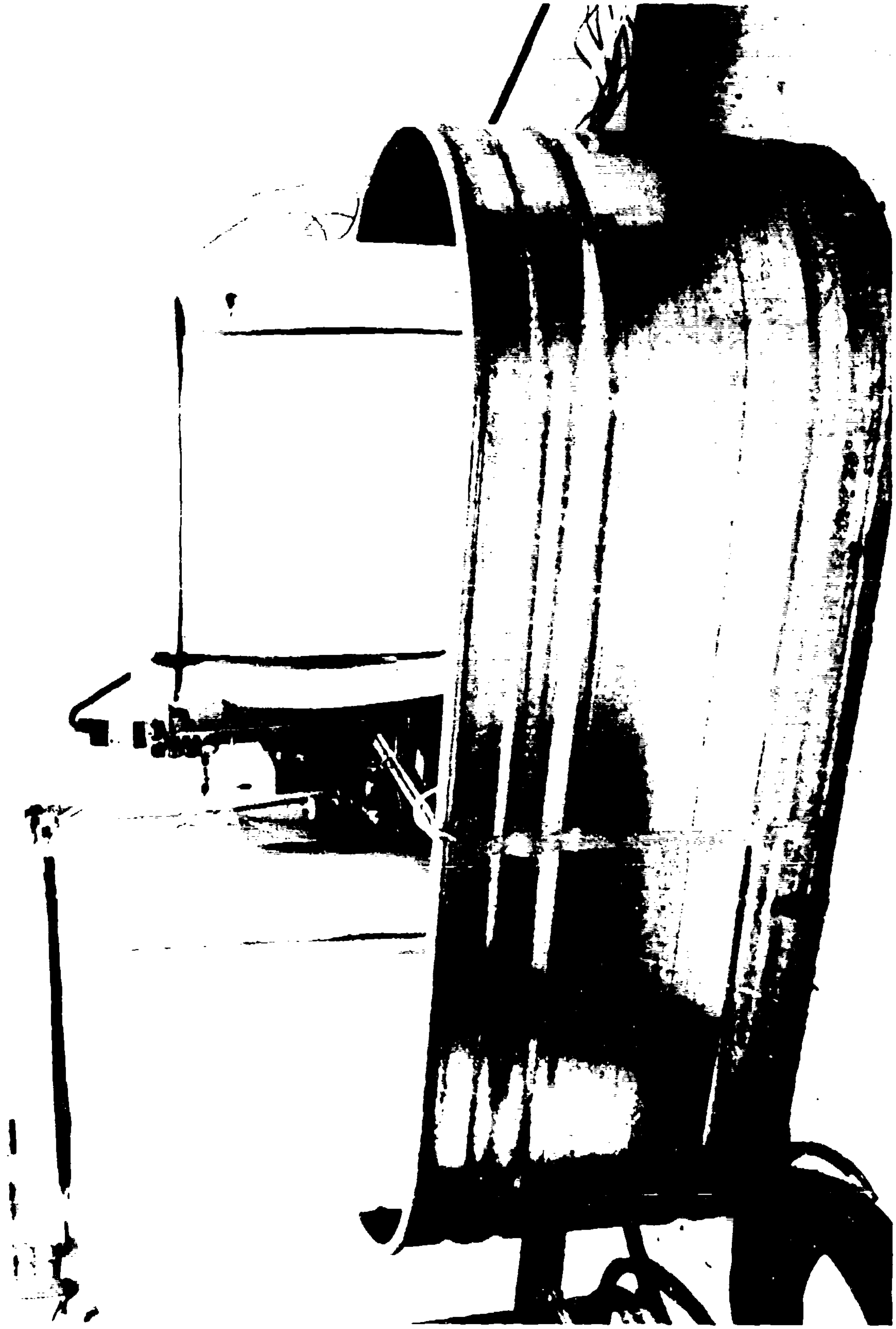


FIGURE 5.33 - FORCED HYDROLYSIS TEST SETUP

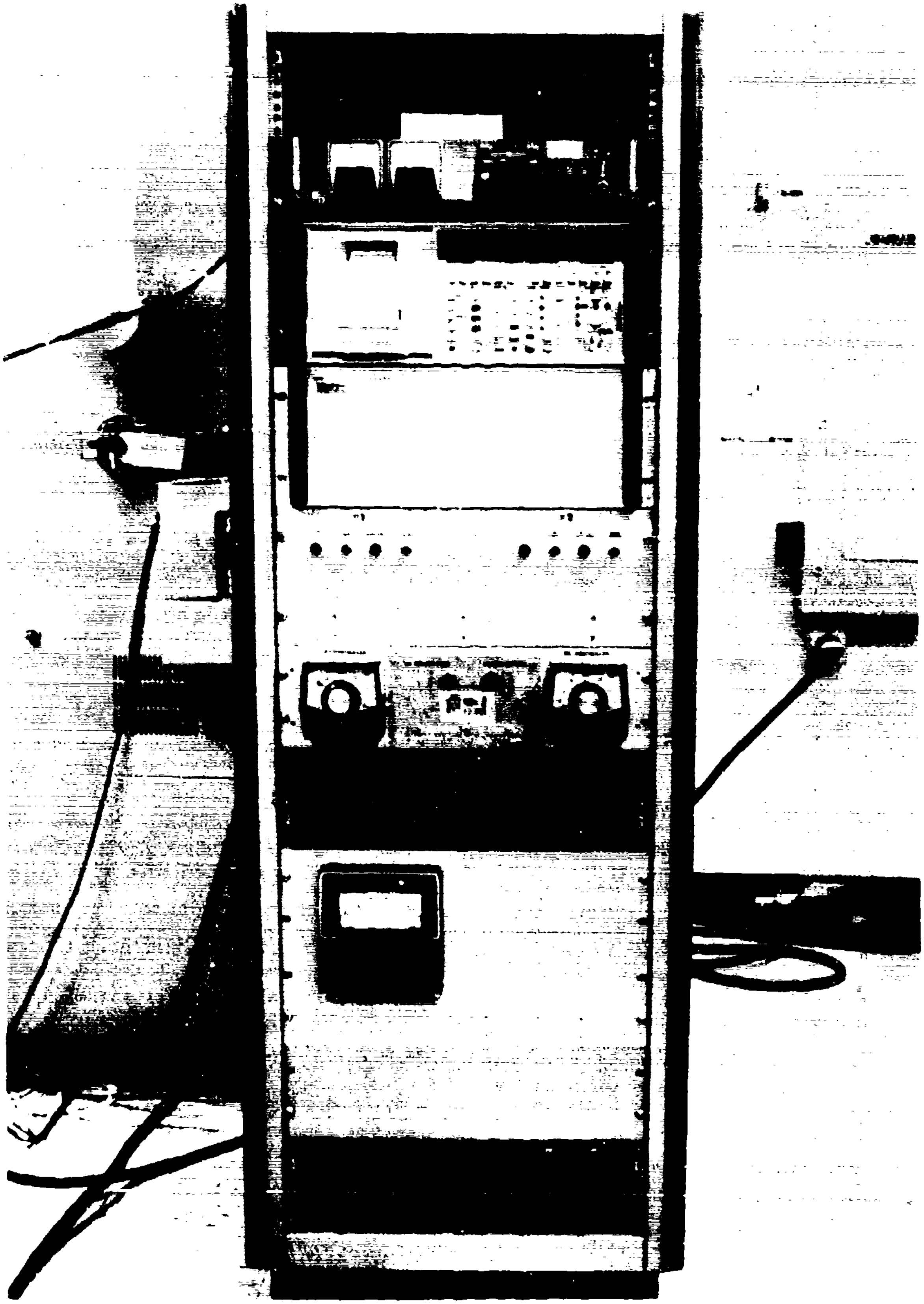


FIGURE 5.34 - FORCED HYDROLYSIS TEST INSTRUMENTATION

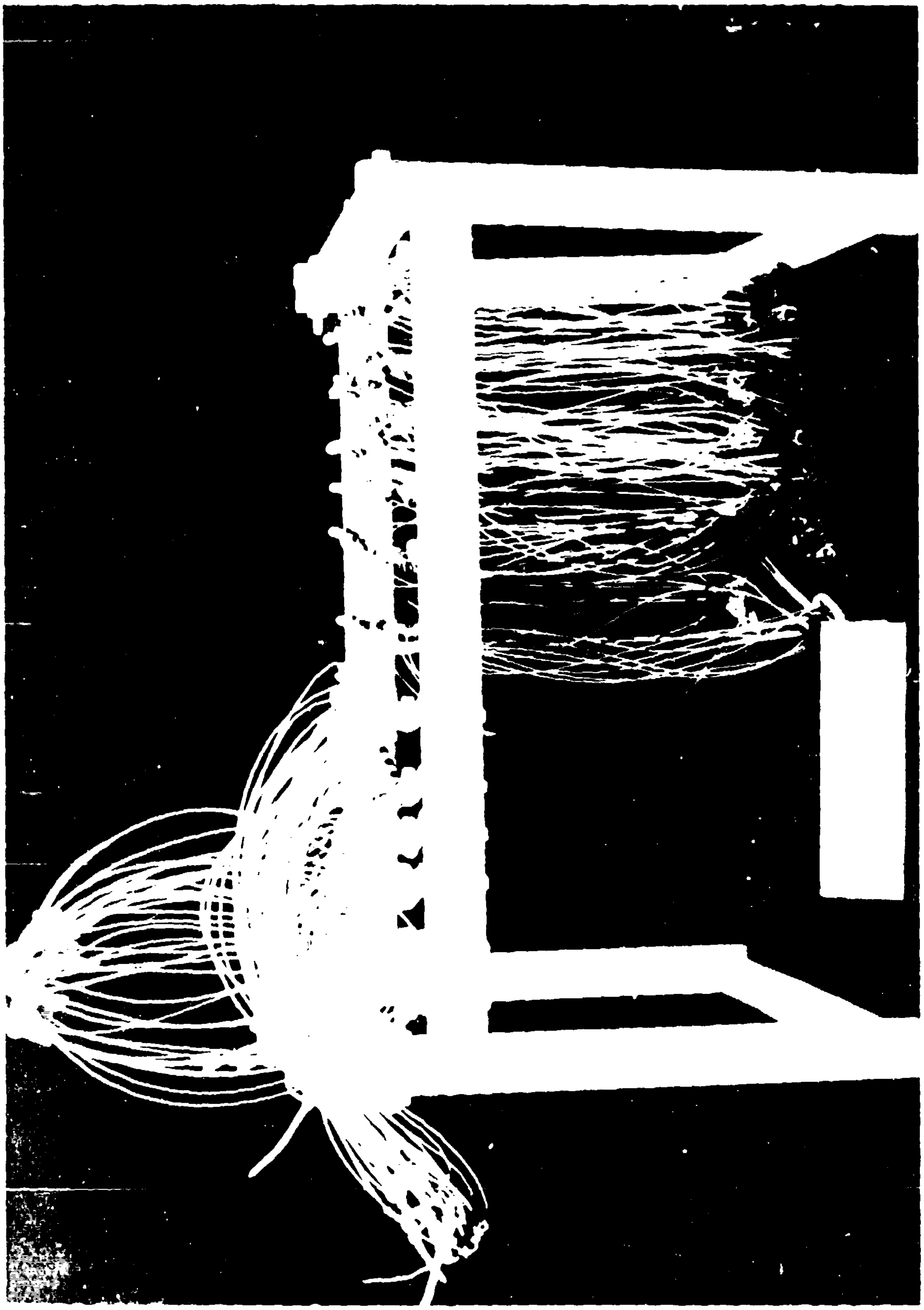


FIGURE 5.35 - FORCED HYDROLYSIS TEST RACK

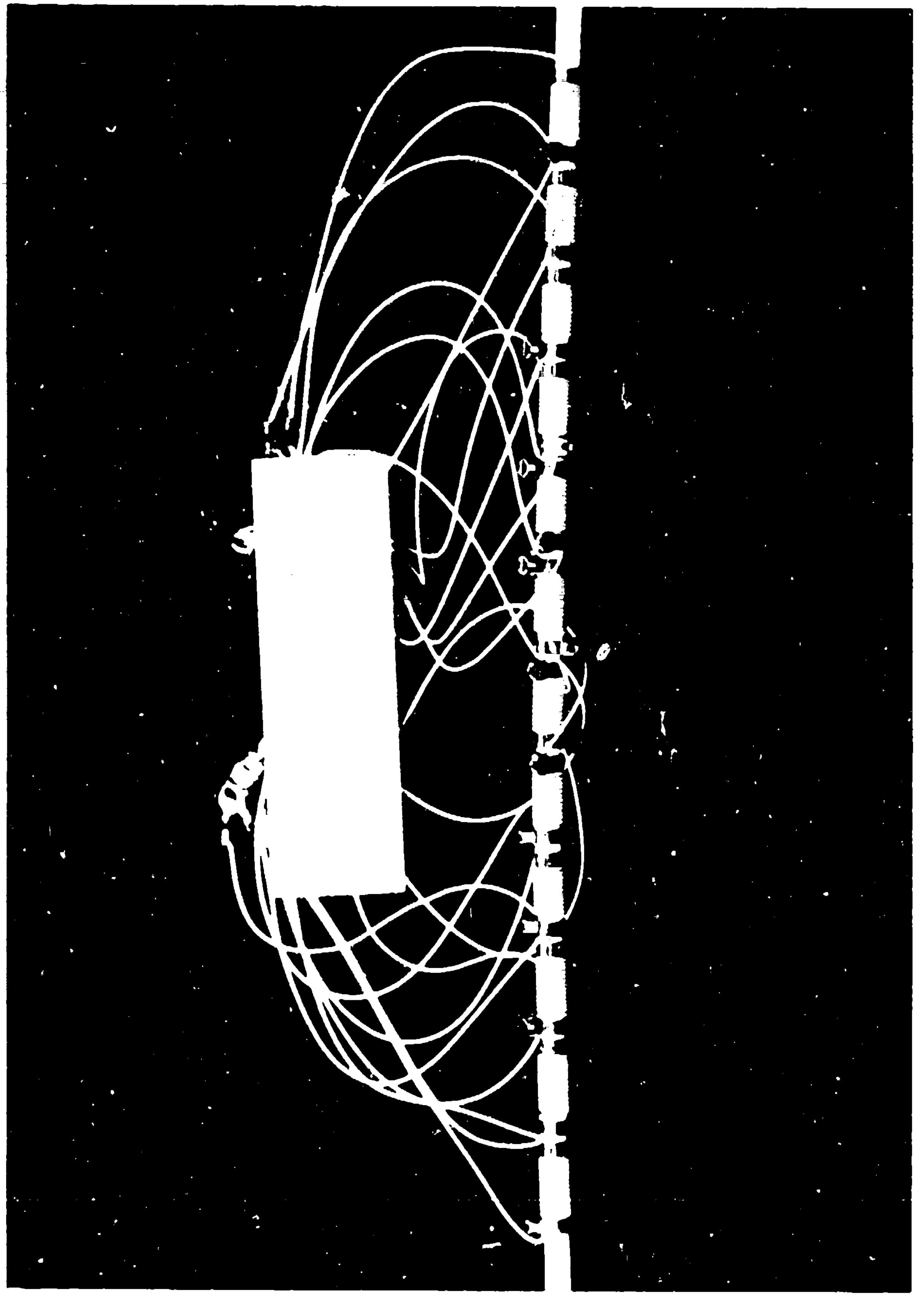


FIGURE 5.36 - FORCED HYDROLYSIS TEST SPECIMENS

5.4.2 HUMIDITY RESISTANCE.

5.4.2.1 Scope: The Humidity Resistance Test was used to determine the effects of humidity and temperature cycling on the insulation of the wire sample.

5.4.2.2 Reference Procedure: The Humidity Resistance Test was conducted according to Method 603 of SAE AS4373. After the completion of the humidity and temperature cycling, the specimens underwent an Insulation Resistance Test, Method 504 of SAE AS4373.

5.4.2.3 Specimens: Specimens were constructed for 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. One specimen of each cable sample was cut to a length of 52 feet. The specimens were coiled into eight inch diameter loops and loosely tied with a fiberglass (MIL-43435B, type IV) lacing tape to retain the coiled configuration. The specimens were identified by stamping ID numbers on aluminum tags and securing the tag to the specimens with the fiberglass lacing tape.

5.4.2.4 Test Equipment: A Tenney Engineering five cubic foot Benchmaster Temperature/Humidity Chamber, Model BTRS, (MD 082697) was used to conduct the humidity exposure.

A Beckman Megohmmeter (MD 078996) was used to acquire the insulation resistance measurements at 500 volts, dc.

Photographs of the test setup and equipment are presented in Figures 5.38 through 5.39.

5.4.2.5 Test Procedure: The specimens were laid on metal racks in a manner to promote air circulation within the chamber. The specimens and racks were placed inside the chamber with the specimens evenly spaced. The chamber temperature was raised to 70±3°C (158±5°F) with a humidity value of 95±5% over a two hour period. The specimens were exposed to the temperature of 70±3°C (158±5°F) at a humidity value of 95±5% for a 6 hour period. At the end of the six hour period, the temperature was lowered to 38±3°C (100±5°F) over a 16 hour period with a constant humidity value of 95±5%. The two hours heating, six hours at high temperature, and 16 hours cooling comprised one cycle. The specimens were exposed to 15 cycles of heating, high temperature, and cooling for a total test exposure of 360 hours. At completion of the fifteenth cycle, the specimens were allowed to return to room ambient and subjected to an Insulation Resistance Test according to Method 504 of SAE AS4373.

Prior to the Insulation Resistance Test, the specimens were terminated. The specimens had a quarter inch of insulation removed from both ends of the specimen and a

#10 ring terminal was crimped on the conductors. The specimens were coiled and secured to a terminal strip with both ends of the specimen connected to a common point. The coiled specimens were immersed to within 12 inches of their ends in a water solution containing 0.10% wetting agent (Aerosol OT) for a four hour soak. At completion of the four hour soak, a potential was applied between the specimen and an electrode placed in the solution. A potential of 500 volts DC was applied for one minute before an insulation resistance measurement was acquired. The acquired value was converted to a value of megohms-1000 feet. The insulation resistance measurement was made and the calculated megohms-1000 feet was recorded. The specimens were also inspected for cracks, color change, and any other anomalies. If the specimen was identified with any of the anomalies stated, the specimen was labeled a failure.

5.4.2.6 Test Results: The results of the insulation inspection, measured insulation resistance value, and the calculated insulation resistance value for a 1000 foot segment is presented in Tables 5.38 through 5.40 with graphical representation of the data presented in Figure 5.37.

TABLE 5.38 - HUMIDITY RESISTANCE TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INSULATION INSPECTION (P / F)	MEASURED INSULATION RESISTANCE 50 FEET (MEGOHMS)	CALCULATED INSULATION RESISTANCE 1000 FEET (MEGOHMS)
201	M81381	6 / 0	350,000	17,500
206	M22759	6 / 0	2,000,000	100,000
236	FILOTEX	6 / 0	1,000,000	50,000
241	TENSOLITE #3	6 / 0	600,000	30,000
246	THERMATICS #3	6 / 0	500,000	25,000
256	NEMA #3	6 / 0	500,000	25,000

TABLE 5.39 - HUMIDITY RESISTANCE TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INSULATION INSPECTION (P / F)	MEASURED INSULATION RESISTANCE 50 FEET (MEGOHMS)	CALCULATED INSULATION RESISTANCE 1000 FEET (MEGOHMS)
202	M81381	6 / 0	100,000	5,000
207	M22759	6 / 0	2,000,000	100,000
237	FILOTEX	6 / 0	900,000	45,000
242	TENSOLITE #3	6 / 0	1,100,000	55,000
247	THERMATICS #3	6 / 0	40,000	2,000
257	NEMA #3	6 / 0	600,000	30,000

TABLE 5.40 - HUMIDITY RESISTANCE TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INSULATION INSPECTION (P / F)	MEASURED INSULATION RESISTANCE 50 FEET (MEGOHMS)	CALCULATED INSULATION RESISTANCE 1000 FEET (MEGOHMS)
203	M81381	6 / 0	190,000	9,500
208	M22759	6 / 0	4,000,000	200,000
238	FILOTEX	6 / 0	1,400,000	70,000
243	TENSOLITE #3	6 / 0	2,000,000	100,000
248	THERMATICS #3	6 / 0	100,000	5,000
258	NEMA #3	6 / 0	1,200,000	60,000

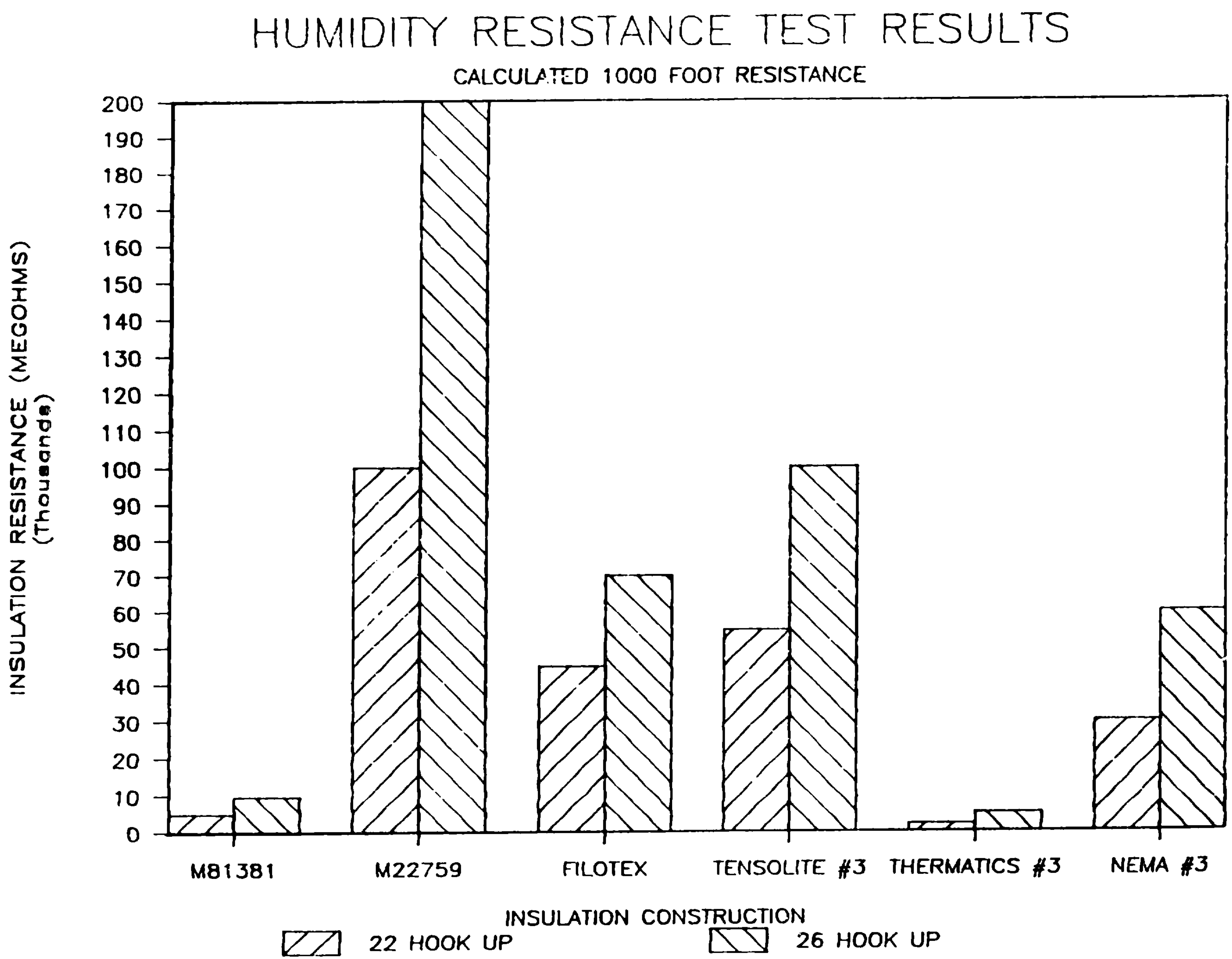


FIGURE 5.37 - HUMIDITY RESISTANCE TEST RESULTS,
CALCULATED 1000 FOOT RESISTANCE

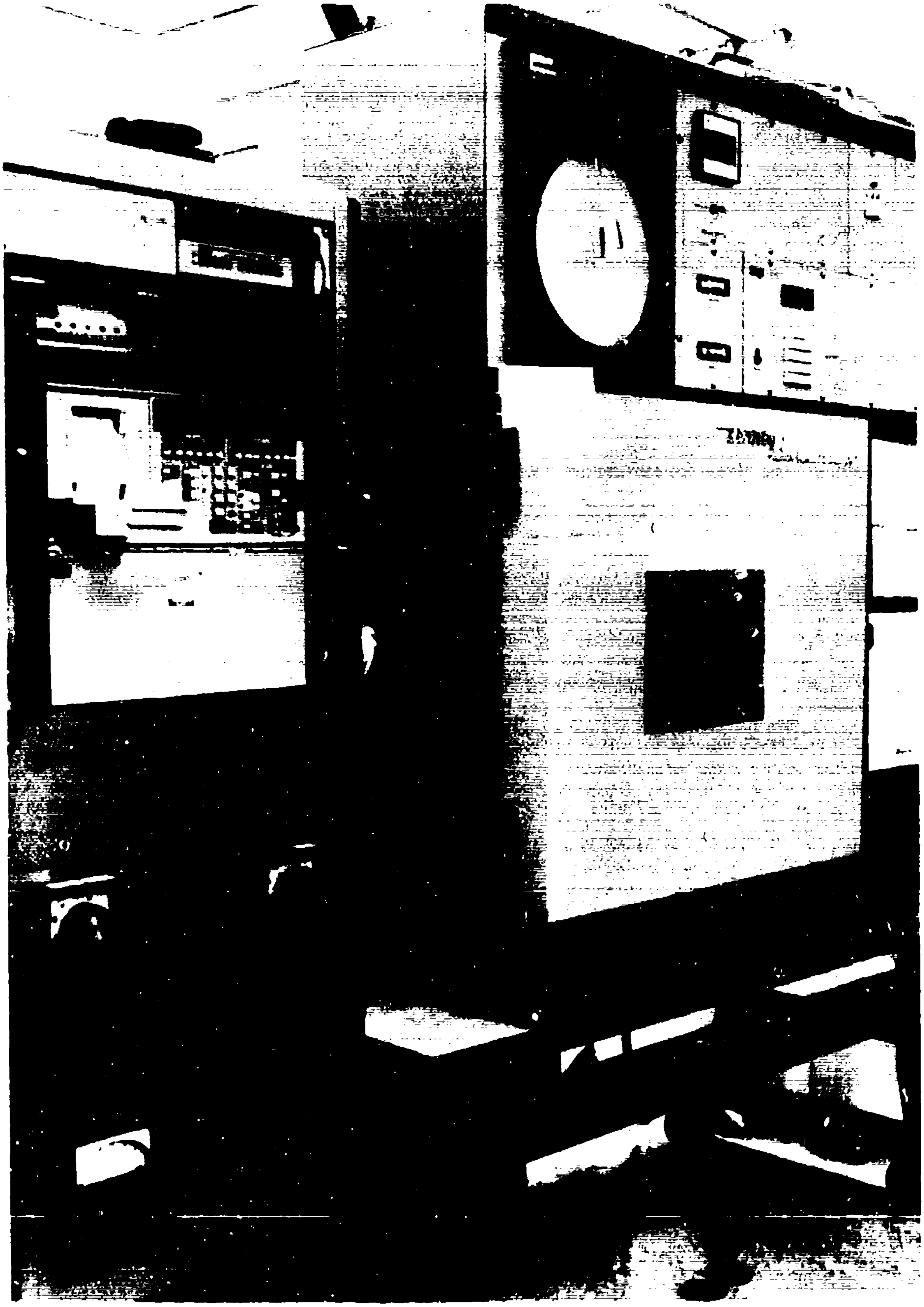


FIGURE 5.38 - HUMIDITY RESISTANCE TEST SETUP

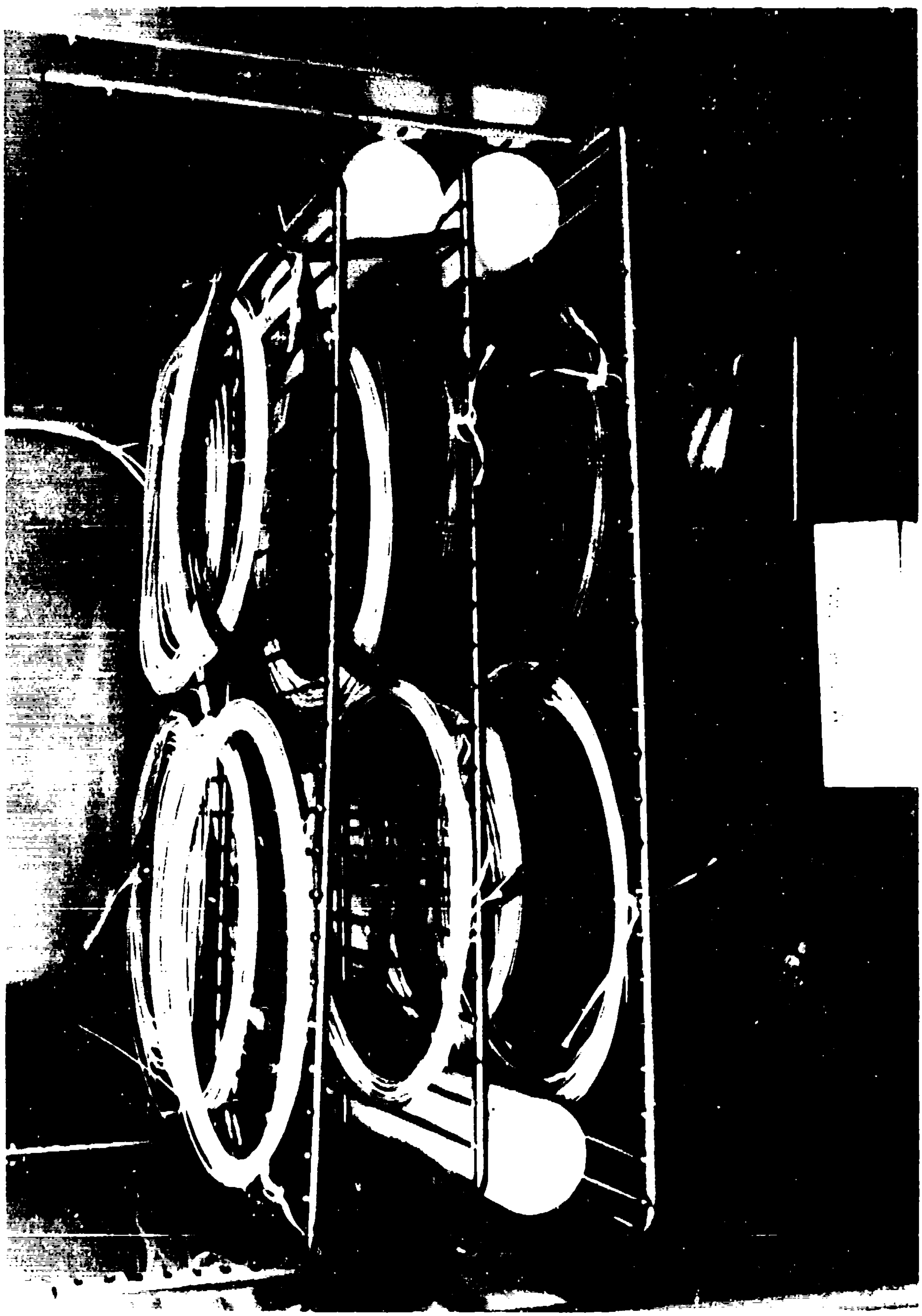


FIGURE 5.39 - HUMIDITY RESISTANCE TEST CHAMBER

5.4.3 WEIGHT LOSS (OUTGASSING) UNDER TEMPERATURE AND VACUUM.

5.4.3.1 Scope: The Weight Loss Under Temperature and Vacuum Test was used to determine the the weight loss of preconditioned insulated wire and cable when subjected to a vacuum at temperature.

5.4.3.2 Reference Procedure: The Weight Loss Under Temperature and Vacuum Test was conducted according to Method 604 of SAE AS4373. One set of six specimens of each sample was preconditioned at 96% relative humidity at 38°C (100°F) for 72 hours. Another set of six specimens of each sample was conditioned at less than 5% relative humidity at 38°C (100°F) for 72 hours.

Due to limitations of the heaters inside the altitude chamber, the pressure was only reduced to 36 Torr instead of 33 Torr.

5.4.3.3 Specimens: Specimens were constructed for 22 gauge, 8.6 mil wall, airframe wire and 22 gauge, two conductor, twisted, shielded and jacketed cable. Twelve specimens of each sample were cut to a length of 24 inches. The specimens were wrapped into a coil approximately 3.5 inches in diameter. The specimens were identified by their position in the racks. Plastic gloves were used when handling the specimens to provide accurate weight measurements.

5.4.3.4 Test Equipment: A Tenney Engineering five cubic foot Benchmaster Temperature/Humidity Chamber, Model BTRS, (MD 082697) was used to conduct the 96% relative humidity preconditioning exposure. Wet and dry bulb measurements were acquired to determine the percentage of relative humidity inside the chamber during the test.

A Blue M oven was sealed to sustain the low humidity level. A 115 volt, 135 watt, strip heater controlled by a variable transformer was used to control the temperature within the chamber. Air circulation within the chamber was supplied by a small muffin fan. The humidity was measured by an Omega Humidity/Temperature Sensor. To achieve the low humidity levels, several bags of Desiccant ($CaSO_4$) were placed in the bottom of the oven to absorb the moisture.

A Mettler PT320 Electronic Scale (MD 083790) was used to conduct the weight measurements. The scale has the ability of measuring to the nearest thousandth of a gram.

A 2240B Fluke Datalogger (MD 078915) was used to record the temperature and humidity measurements within the two preconditioning environmental chambers.

A Tenney seven Foot Environmental Test Chamber, was used to subject the specimens to altitude. A cylindrical quartz lamp bank was placed inside the altitude chamber to provide the elevated temperature of 200°C (392°F). The specimens were placed on rods and centered within the lamp bank for the temperature/altitude sequence of the

test.

Photographs of the conditioning chambers and specimens are presented in Figures 5.42 through 5.44.

5.4.3.5 Test Procedure: All specimens were initially cleaned using a dry piece of cheesecloth and weighed prior to any preconditioning. All measurements were recorded.

One set of six specimens were exposed to 96% relative humidity at 38°C (100°F) for 72 hours in the Tenney Temperature Humidity Chamber. At the same time, another set of six specimens were conditioned at less than 5% relative humidity at 38°C (100°F) for 72 hours in the sealed Blue M Oven. Upon completion of the two preconditioning exposures, the specimens were weighed within one hour of their removal.

Within one hour after removal from the preconditioning chamber and weighing, both sets of specimens were transferred to a temperature altitude chamber preconditioned to 200°C (392°F). The chamber was sealed and the pressure was reduced to 36 Torr. The specimens remained at a temperature of 200°C (392°F) with a pressure of 36 Torr for 384 hours. At the completion of the 384 hour exposure, the specimens were removed from the chamber and weighed within one hour to acquire a weight loss (outgassing) value.

The initial weight, post conditioned weight, and the final weights were recorded. The calculated weight loss value was determined by subtracting the post conditioned measurement from the final measurement. The percentage weight loss value was determined by the following relationship.

$$\% \text{ Weight Loss} = [(W_{final} - W_{cond.})/W_{cond.}] \times 100$$

5.4.3.6 Test Results: The average percentage weight loss (outgassing) for specimens conditioned at 5% and 95% relative humidity is presented in Tables 5.41 through 5.42 with graphical representation of the data presented in Figures 5.40 through 5.41.

TABLE 5.41 - WEIGHT LOSS (OUTGASSING) TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE PERCENTAGE WEIGHT LOSS (CONDITIONED 5% REL. HUM.)	AVERAGE PERCENTAGE WEIGHT LOSS (CONDITIONED 95% REL. HUM.)
201	M81381	0.000	- 0.394
206	M22759	- 0.189	- 0.269
236	FILOTEX	- 0.065	- 0.231
241	TENSOLITE #3	+ 0.039	- 0.045
246	THERMATICS #3	+ 0.029	- 0.164
256	NEMA #3	- 0.099	- 0.266

TABLE 5.42 - WEIGHT LOSS (OUTGASSING) TEST RESULTS ON 22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE PERCENTAGE WEIGHT LOSS (CONDITIONED 5% REL. HUM.)	AVERAGE PERCENTAGE WEIGHT LOSS (CONDITIONED 95% REL. HUM.)
204	M81381	- 0.234	- 0.563
209	M22759	- 0.085	- 0.110
239	FILOTEX	- 0.037	- 0.263
244	TENSOLITE #3	- 0.006	- 0.072
249	THERMATICS #3	- 0.020	- 0.159
259	NEMA #3	- 0.048	- 0.224

The average increase in weight of the Tensolite and Thermatics 22 gauge, 8.6 mil wall, airframe wire are a result of measurement error.

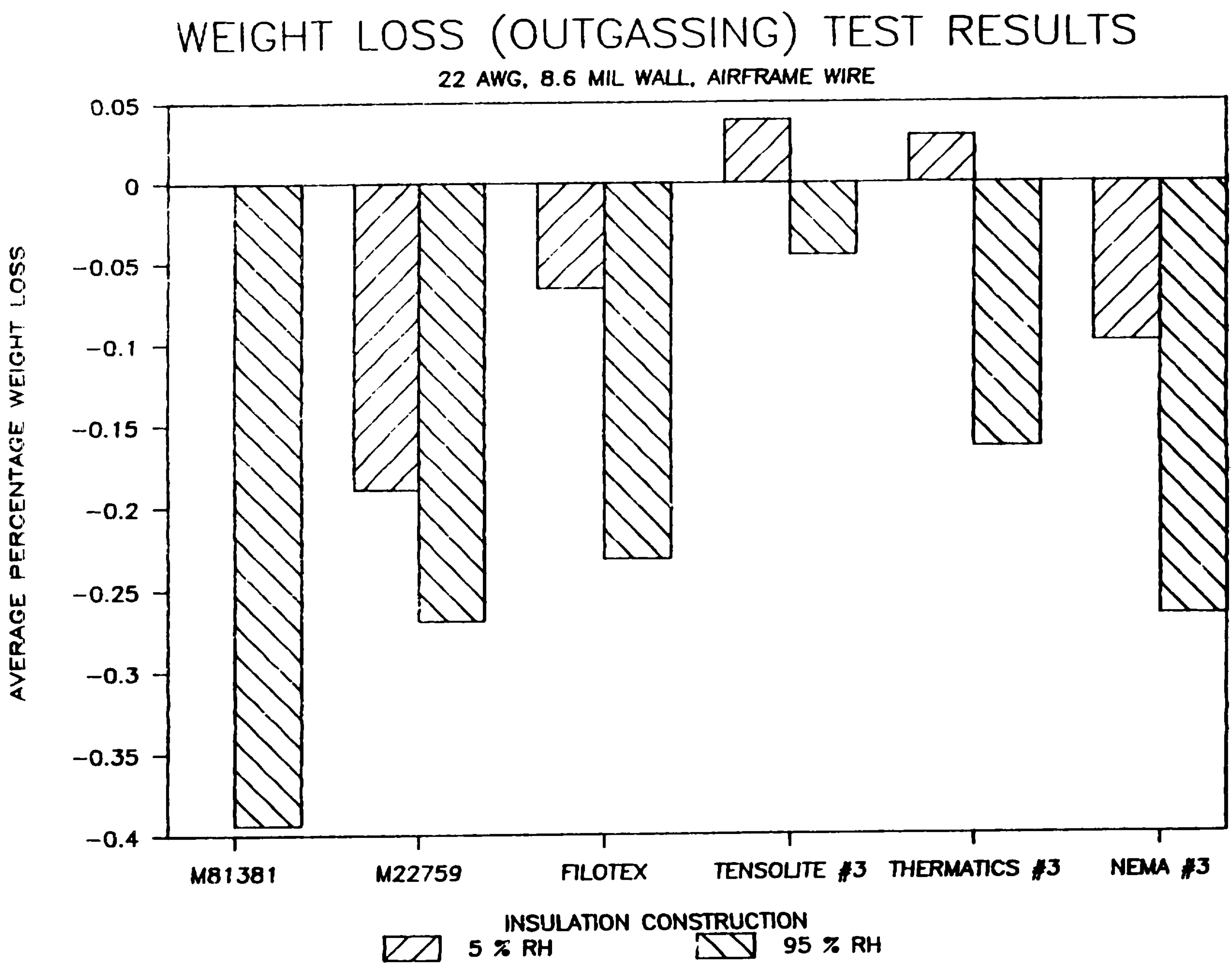


FIGURE 5.40 - WEIGHT LOSS (OUTGASSING) TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

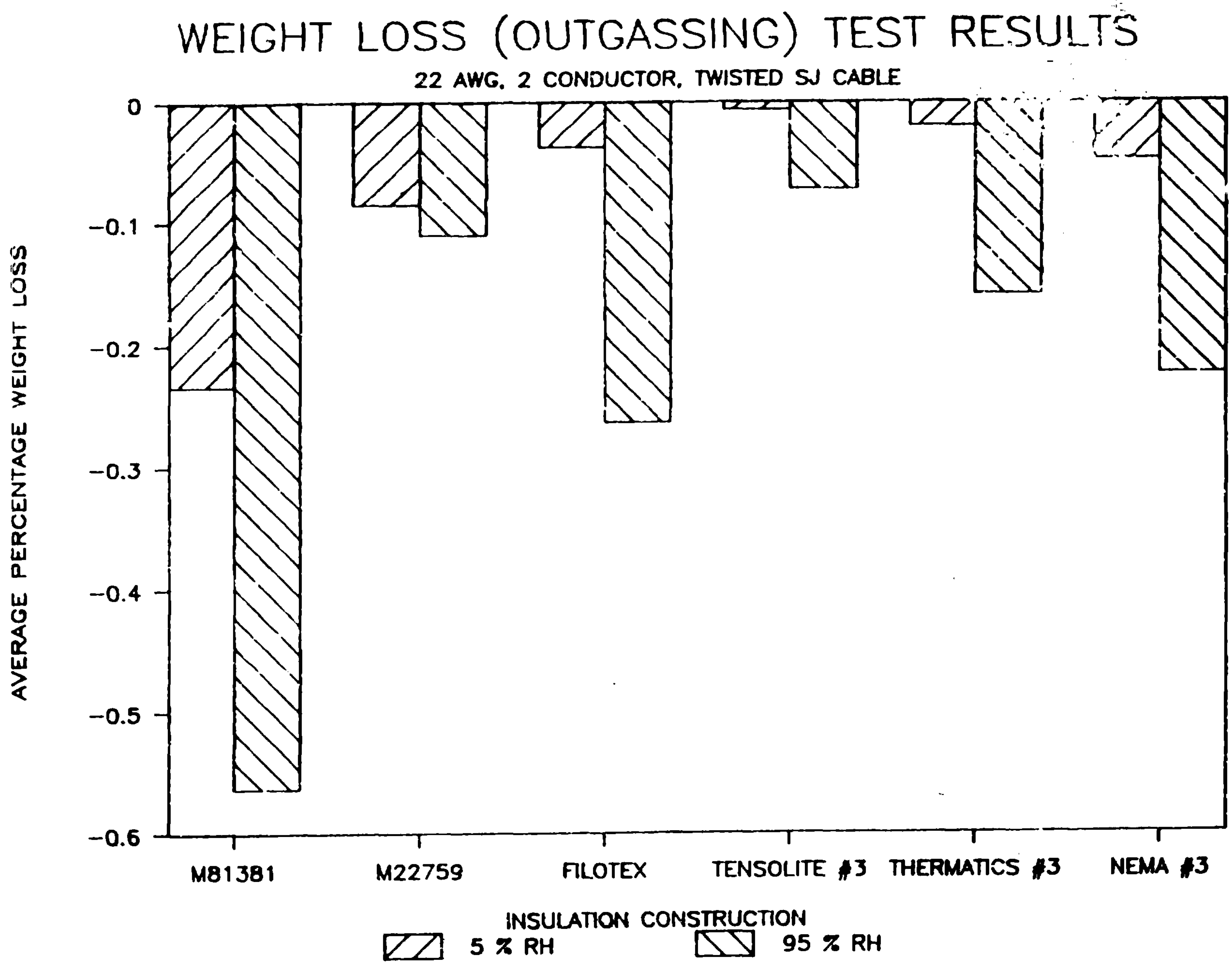


FIGURE 5.41 - WEIGHT LOSS (OUTGASSING) TEST RESULTS, 22AWG, 2 CONDUCTOR, TWISTED SJ CABLE

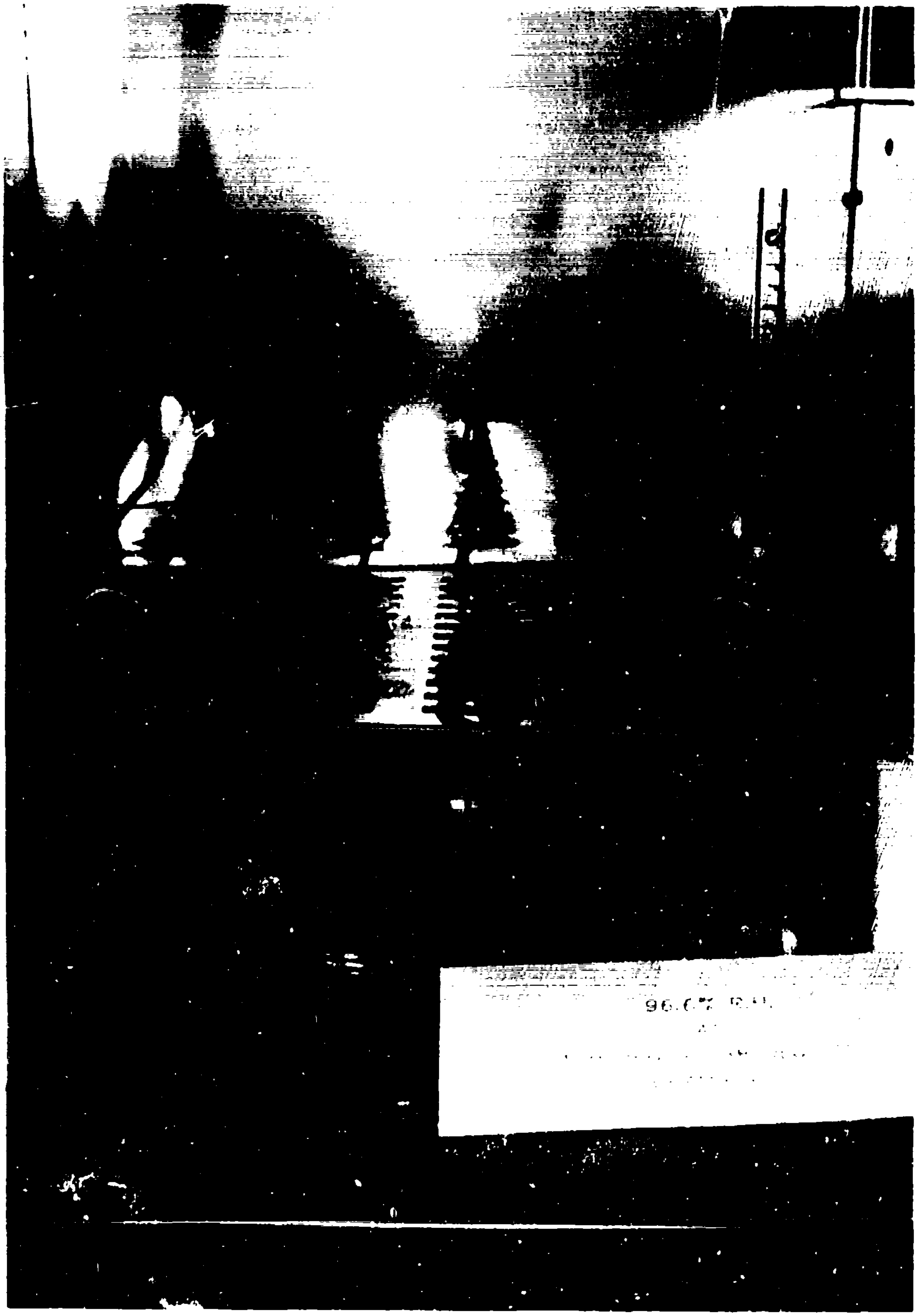


FIGURE 5.44 - WEIGHT LOSS (OUTGASSING) 95% R.H. TEST SPECIMENS

5.4.4 WEATHERING RESISTANCE.

5.4.4.1 Scope: The Weathering Resistance Test was used to determine the effects of ultraviolet light and condensation exposure on the insulation of the wire sample.

5.4.4.2 Reference Procedure: The Weathering Resistance Test was conducted according to Method 606 of SAE AS4373. After the completion of the 120 ultraviolet/condensation cycles, the specimens underwent a Bend Test, Method 714 of SAE AS4373, and a Voltage Withstand Test, Method 510 of SAE AS4373.

5.4.4.3 Specimens: Specimens were constructed for 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; 26 gauge, 5.8 mil wall, hook up wire; and 22 gauge, two conductor, twisted, shielded and jacketed cable. Six unterminated specimens of 36 inches in length were constructed from each of the samples. The specimens were secured to a base plate of the ultraviolet condensation chamber by three equidistant metal strips. The specimens were identified by stamping the ID numbers on aluminum tags and loosely securing the tags to the specimens using Nylon ty-raps.

Photographs of the specimens and mounting plates are presented in Figures 5.46 through 5.47.

5.4.4.4 Test Equipment: An Atlas Ultraviolet/Condensation Screening Device (MD 96398) conforming to the requirements of ASTM G53 was used.

Mandrels were constructed for use in the Bend Test. The mandrel diameters used were approximately fifty times the maximum diameter of the samples. The diameter measurements were acquired from the Finished Wire and Cable Diameter Test. The mandrel diameters used were 2.375 inches for the 22 gauge, 8.6 mil wall, specimens; 2.0 inches for the 22 gauge, 5.8 mil wall, specimens; 1.5 inches for the 26 gauge, 5.8 mil wall, specimens; and 4.75 inches for the 22 gauge cable specimens.

A Slaughter Dielectric Tester (MD 78995) was used to conduct the Voltage Withstand Test. The voltage was monitored by a Fluke 8050A Digital Multimeter (MD 011821) through a Fluke 80K-6 High Voltage Probe (MD 189698).

5.4.4.5 Test Procedure: The specimens were mounted on an aluminum rack in the chamber and exposed to 120 cycles of ultraviolet light and condensation. One cycle consisted of exposure to eight hours of ultraviolet light at 70±3°C (158±5°F) and then to four hours of condensation at 40±3°C (104±5°F). After completion of the 120 cycles, the specimens were inspected for cracking, color change, and visible changes to the insulation prior to the Bend Test and Voltage Withstand Test.

The specimens were terminated prior to the additional tests. The wire specimens had a quarter inch of insulation removed from both ends and #10 ring terminals crimped on the conductors. The cable specimens were prepared by removing 1.5 inches of the jacket and pushing the shield back. The conductors had a quarter inch of insulation removed from each primary wire. One end of the specimen had the conductors twisted together and a #10 ring terminal crimped on the twisted conductor pair. The other end of the specimen had #10 ring terminals crimped on each individual conductor.

The specimens were subjected to a Bend Test, Method 714 of SAE AS4373. The specimens were attached at one end to the appropriate mandrel with a corresponding weight attached to the other end. The 22 gauge specimens received a weight of 1.0 pound while the 26 gauge specimens received a weight of 0.5 pounds. The 22 gauge cable specimens had a 1.0 pound weight applied to each conductor. The mandrel diameters used were 2.375 inches for the 22 gauge, 8.6 mil wall, specimens; 2.0 inches for the 22 gauge, 5.8 mil wall, specimens; 1.5 inches for the 26 gauge, 5.8 mil wall, specimens; and 4.75 inches for the 22 gauge cable specimens. The mandrel was rotated at a rate of 15±3 revolutions per minute until the full length of the specimen was wrapped. The mandrel was then rotated in the reverse direction until the full length of the specimen, which was on the outside during the first

wrap, was now next to the mandrel. This was repeated until two wraps in both directions were accomplished. The weights were removed, and the specimens were removed from the mandrels. The cable jacket or wire insulation was inspected for cracking or anomalies and the results were recorded.

A Voltage Withstand Test, Method 510 of SAE AS4373, was conducted on the specimens after completion of the Bend Test. The specimens were secured to a terminal strip with both ends of the specimen common. The specimens were submerged to within two inches of the specimen end in a 5% salt solution with 0.1% wetting agent (Aerosol OT) added. After completion of a four hour soak period, a voltage potential was applied to the specimen to detect cracks. The potential was applied to the specimen at a rate of 500 volts per second until the test voltage was achieved. A test voltage of 2500 volts at 60 Hertz was applied between the conductor of the wire specimens and an electrode placed in the solution. The time of electrification was one minute unless a failure occurred. A failure was defined as a specimen having a leakage current value greater than five milliamps. The largest leakage current at the end of one minute was recorded. If a failure occurred, the time to failure was recorded.

The cable specimens underwent two dielectric tests, the first test applied 1500 volts between the cable shield and the electrode placed in the solution. The second test consisted of applying 1500 volts between the two primary conductors connected in common and the shield connected common with the electrode placed in the solution. The time of electrification was one minute unless a failure occurred. The time to failure was recorded. A failure was defined as a specimen having a leakage current greater than five milliamps. The largest leakage current at the end of one minute was recorded. If a failure occurred, the time to failure was recorded.

5.4.4.6 Test Results: The color changes detected were minor but evident. A color change failure was defined as the insulation's original color diminishing in quality as a result of the ultraviolet and condensation exposure.

The results of the insulation inspection, the Bend Test, The Voltage Withstand Test, and the average leakage current of the specimens that passed the Voltage Withstand Test is presented in Tables 5.43 through 5.47 with graphical representation of the data presented in Figure 5.45.

TABLE 5.43 - WEATHERING RESISTANCE TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INSUL. INSPECT. CRACKING / DELAM. (P / F)	INSUL. INSPECT. COLOR CHANGE (P / F)	BEND TEST RESULTS (P / F)	VOLTAGE WITHSTAND RESULTS (P / F)	AVERAGE LEAKAGE CURRENT (MICRO-AMP)
101	M81381	6 / 0	6 / 0	6 / 0	6 / 0	220
106	M22759	6 / 0	0 / 6	6 / 0	6 / 0	180
136	FILOTEX	6 / 0	6 / 0	6 / 0	6 / 0	170
141	TENSOLITE #3	6 / 0	6 / 0	6 / 0	6 / 0	140
146	THERMATICS #3	6 / 0	0 / 6	6 / 0	6 / 0	250
156	NEMA #3	6 / 0	6 / 0	6 / 0	6 / 0	200

TABLE 5.44 - WEATHERING RESISTANCE TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INSUL. INSPECT. CRACKING / DELAM. (P / F)	INSUL. INSPECT. COLOR CHANGE (P / F)	BEND TEST RESULTS (P / F)	VOLTAGE WITHSTAND RESULTS (P / F)	AVERAGE LEAKAGE CURRENT (MICRO-AMP)
102	M81381	6 / 0	6 / 0	6 / 0	6 / 0	300
107	M22759	6 / 0	6 / 0	6 / 0	6 / 0	232
137	FILOTEX	6 / 0	6 / 0	6 / 0	6 / 0	230
142	TENSOLITE #3	6 / 0	6 / 0	6 / 0	6 / 0	170
147	THERMATICS #3	6 / 0	6 / 0	6 / 0	6 / 0	328
157	NEMA #3	6 / 0	6 / 0	6 / 0	6 / 0	230

TABLE 5.45 - WEATHERING RESISTANCE TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	INSUL. INSPECT. CRACKING / DELAM. (P / F)	INSUL. INSPECT. COLOR CHANGE (P / F)	BEND TEST RESULTS (P / F)	VOLTAGE WITHSTAND RESULTS (P / F)	AVERAGE LEAKAGE CURRENT (MICRO-AMP)
103	M81381	6 / 0	6 / 0	6 / 0	6 / 0	210
108	M22759	6 / 0	6 / 0	6 / 0	6 / 0	170
138	FILOTEX	6 / 0	6 / 0	6 / 0	6 / 0	170
143	TENSOLITE #3	6 / 0	6 / 0	6 / 0	6 / 0	120
148	THERMATICS #3	6 / 0	6 / 0	6 / 0	6 / 0	270
158	NEMA #3	6 / 0	6 / 0	6 / 0	6 / 0	180

TABLE 5.46 - WEATHERING RESISTANCE INSPECTION TEST RESULTS ON 22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	INSULATION INSPECTION CRACKING / DELAM. (P / F)	INSULATION INSPECTION COLOR CHANGE (P / F)	BEND TEST RESULTS (P / F)
104	M81381	6 / 0	6 / 0	6 / 0
109	M22759	6 / 0	0 / 6	6 / 0
239	FILOTEX	6 / 0	6 / 0	6 / 0
144	TENSOLITE #3	6 / 0	6 / 0	6 / 0
149	THERMATICS #3	6 / 0	0 / 6	6 / 0
159	NEMA #3	6 / 0	6 / 0	6 / 0

TABLE 5.47 - WEATHERING RESISTANCE VOLTAGE WITHSTAND TEST RESULTS ON 22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	CONDUCTOR VOLTAGE WITHSTAND RESULTS (P / F)	INSULATION AVERAGE LEAKAGE CURRENT (MICRO-AMP)	SHIELD VOLTAGE WITHSTAND RESULTS (P / F)	JACKET AVERAGE LEAKAGE CURRENT (MICRO-AMP)
104	M81381	6 / 0	403	6 / 0	677
109	M22759	6 / 0	300	6 / 0	373
239	FILOTEX	6 / 0	287	6 / 0	260
144	TENSOLITE #3	6 / 0	263	6 / 0	388
149	THERMATICS #3	6 / 0	583	6 / 0	387
159	NEMA #3	6 / 0	350	6 / 0	337

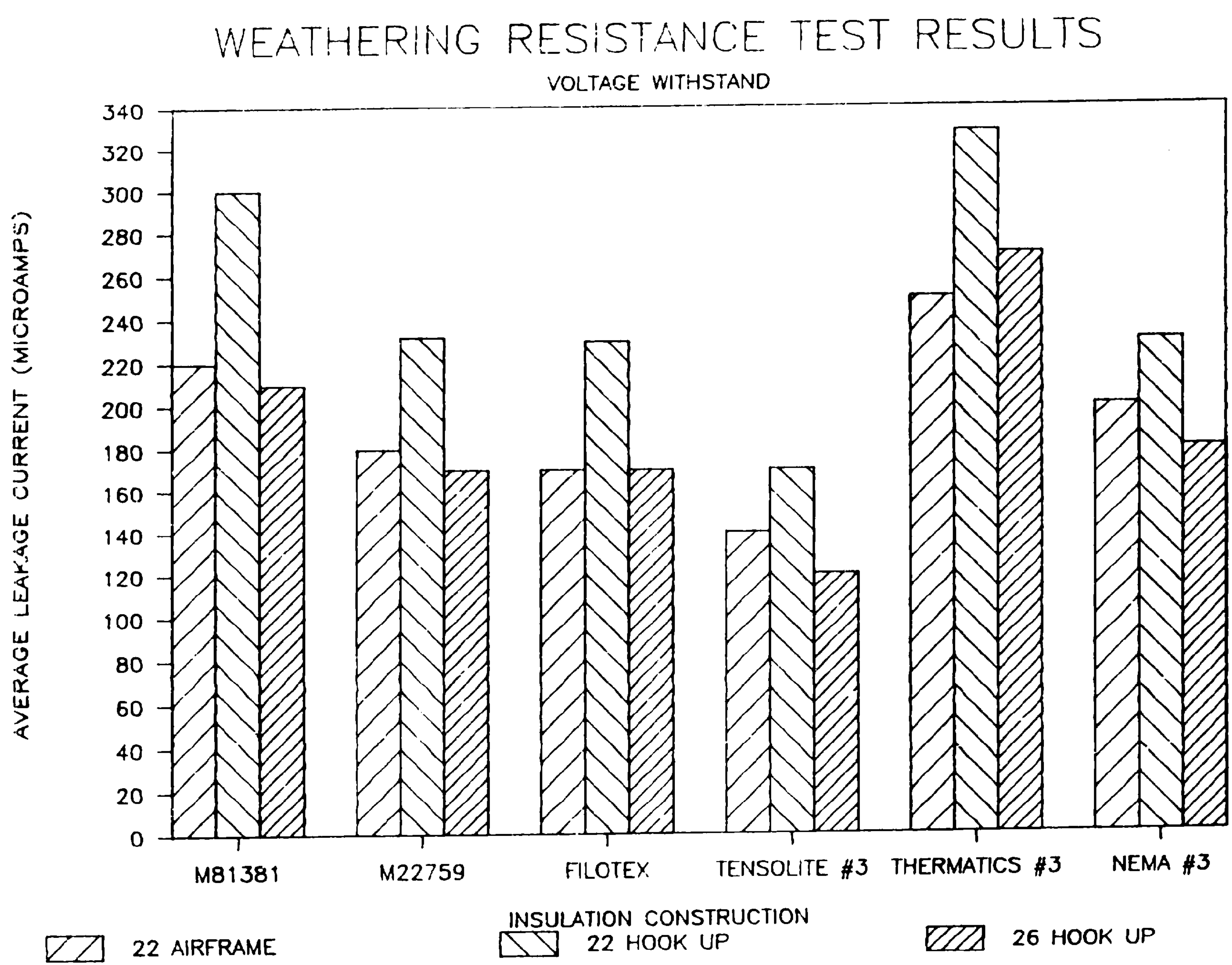


FIGURE 5.45 - WEATHERING RESISTANCE TEST RESULTS, VOLTAGE WITHSTAND

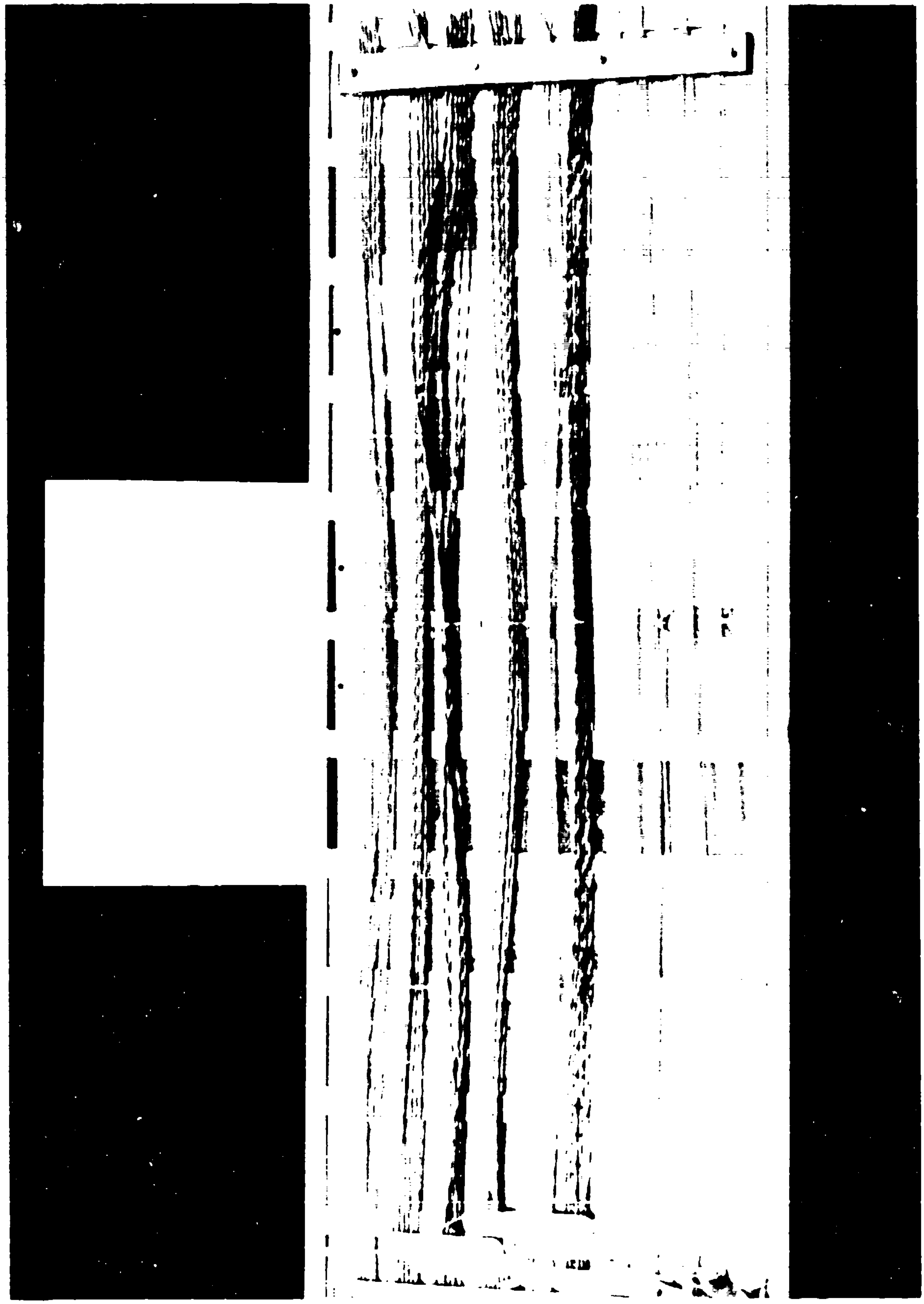


FIGURE 5.46 - WEATHERING RESISTANCE TEST SETUP

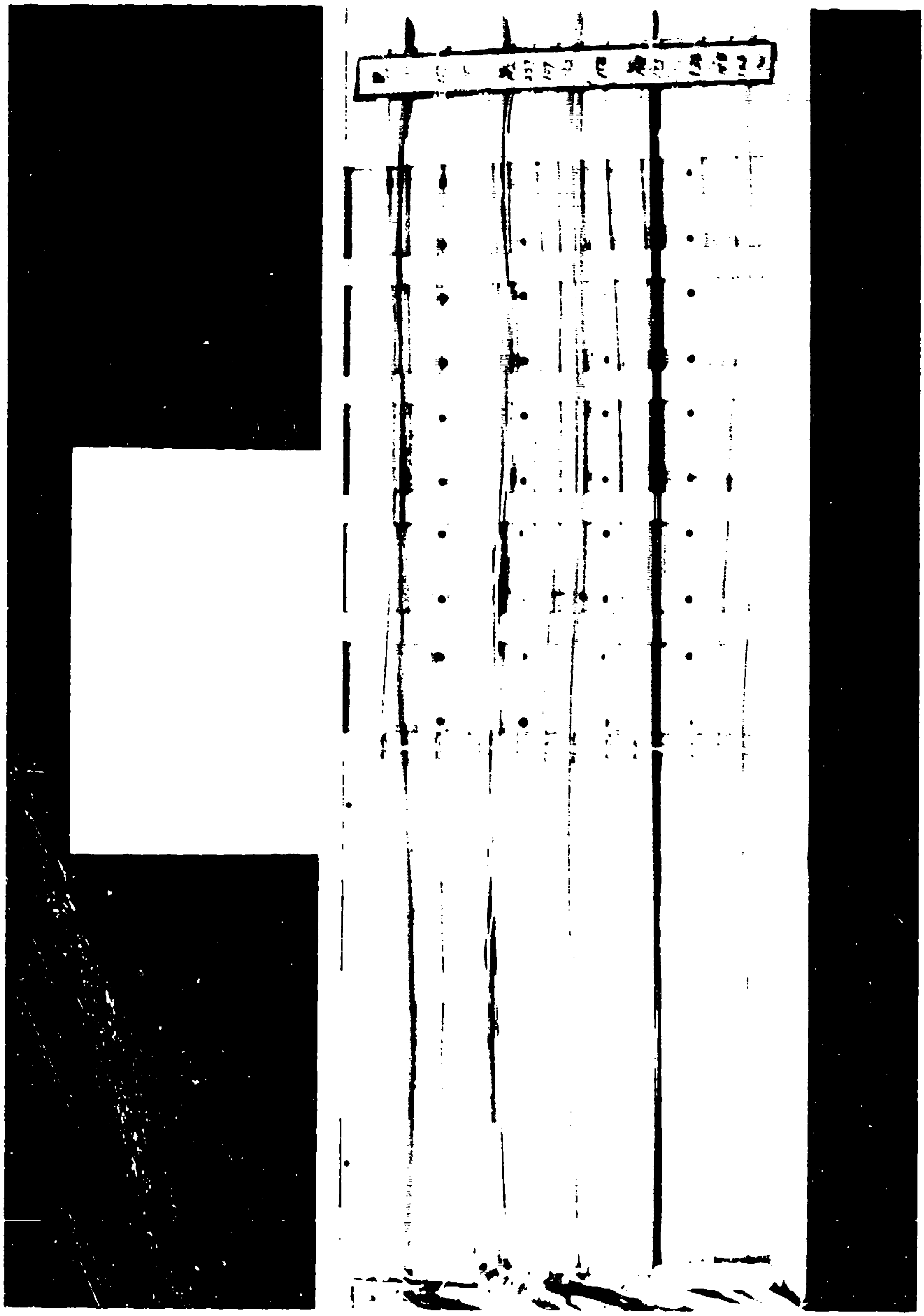


Figure 5.[illegible] - WEATHERING RESISTANCE TEST STRIP

5.4.5 WICKING.

5.4.5.1 Scope: The Wicking Test was used to determine the length of dye travel between layers of insulation.

5.4.5.2 Reference Procedure: The Wicking Test was conducted according to Method 607 of SAE AS4373.

5.4.5.3 Specimens: The Wicking Test was conducted on unconditioned samples of 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. The 22 and 26 gauge, 5.8 mil wall, hook up wire specimens of MIL-W-22759 were excluded because these constructions consisted of a single extruded layer of insulation. Six specimens of each sample were cut to a length of 4.0 inches with the ends cut square using a single ended razor blade.

5.4.5.4 Test Equipment: The test required a dye solution of 0.02 grams of Rhodamine B dissolved in 30 milliliters of ethyl alcohol. This solution was mixed with three milliliters of Aerosol OT and diluted to two liters using distilled water. The test solution was prepared by the Chemical Analysis Laboratory. Caution was taken to use solvent proof gloves during handling of the solution.

The specimens were mounted on four 5 x 2.5 x 0.125 inch Teflon sheets. The width of the Teflon sheets were

matched to the diameter of the 400 milliliter beakers so that the specimens stood upright in the test solution.

A 20 power Bausch and Lomb microscope (MD 121434) was used to assist the technician with acquiring measurements of dye travel.

A photograph of a set of specimens in solution is presented in Figure 5.48.

5.4.5.5 Test Procedure: A set of six specimens was mounted a quarter inch from one side of a 5 x 2.5 x 0.125 inch Teflon sheet for immersion into the dye solution. The Teflon sheet and specimens were placed upright in a 400 milliliter beaker. The dye solution was added to the beaker until 2.0 inches of the specimen's length was submerged in the solution. The specimens remained in the solution for a period of 24 hours at room temperature. After the completion of the soak time, the specimens were removed from the solution and carefully patted dry using cheesecloth. Within five minutes of the removal from the solution, the specimens were visually inspected for dye travel under an ultraviolet light. The maximum length of dye travel between layers of insulation was acquired using a steel scale with 0.0625 inch graduations and a microscope. The layers of insulation were dissected away, starting at the untested end, using an X-acto knife to facilitate observation.

5.4.5.6 **Test Results:** The test results on the specimens showed no signs of dye travel. After reviewing the results of the Wicking Test on wire specimens, the effectiveness of the wicking solution was questioned. The MCAIR Principal Investigator was notified of the test results. It was requested that one specimen of each sample of 22 and 26 gauge, two conductor, twisted, shielded and jacketed cable be tested as described in the Wicking Test procedure. The test was expanded to determine the amount of wicking between layers of the cable jacket instead of the insulation.

The test results of the Wicking Tests are presented in Tables 5.48 through 5.52. On several of the specimens tested, a purplish colored stain was observed on the insulation of th two inches submerged in the Wicking solution. These specimens are identified with asterisks (*).

TABLE 5.48 - WICKING TEST RESULTS ON
22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE LENGTH OF WICKING BETWEEN LAYERS OF INSULATION (INCHES)
101	M81381	0.00
106	M22759	* 0.00
136	FILOTEX	* 0.00
141	TENSOLITE #3	* 0.00
146	THERMATICS #3	0.00
156	NEMA #3	* 0.00

TABLE 5.49 - WICKING TEST RESULTS ON
22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE LENGTH OF WICKING BETWEEN LAYERS OF INSULATION (INCHES)
102	M81381	0.00
107	M22759	----
137	FILOTEX	* 0.00
142	TENSOLITE #3	* 0.00
147	THERMATICS #3	0.00
157	NEMA #3	* 0.00

TABLE 5.50 - WICKING TEST RESULTS ON
26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE LENGTH OF WICKING BETWEEN LAYERS OF INSULATION (INCHES)
103	M81381	0.00
108	M22759	----
138	FILOTEX	* 0.00
143	TENSOLITE #3	* 0.00
148	THERMATICS #3	0.00
158	NEMA #3	* 0.00

TABLE 5.51 - WICKING TEST RESULTS ON
22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE LENGTH OF WICKING BETWEEN LAYERS OF JACKET (INCHES)
104	M81381	0.00
109	M22759	0.00
239	FILOTEX	0.00
144	TENSOLITE #3	* 0.00
149	THERMATICS #3	0.00
159	NEMA #3	0.00

TABLE 5.52 - WICKING TEST RESULTS ON
26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE LENGTH OF WICKING BETWEEN LAYERS OF JACKET (INCHES)
105	M81381	0.00
110	M22759	0.00
240	FILOTEX	0.00
145	TENSOLITE #3	* 0.00
150	THERMATICS #3	0.00
160	NEMA #3	0.00

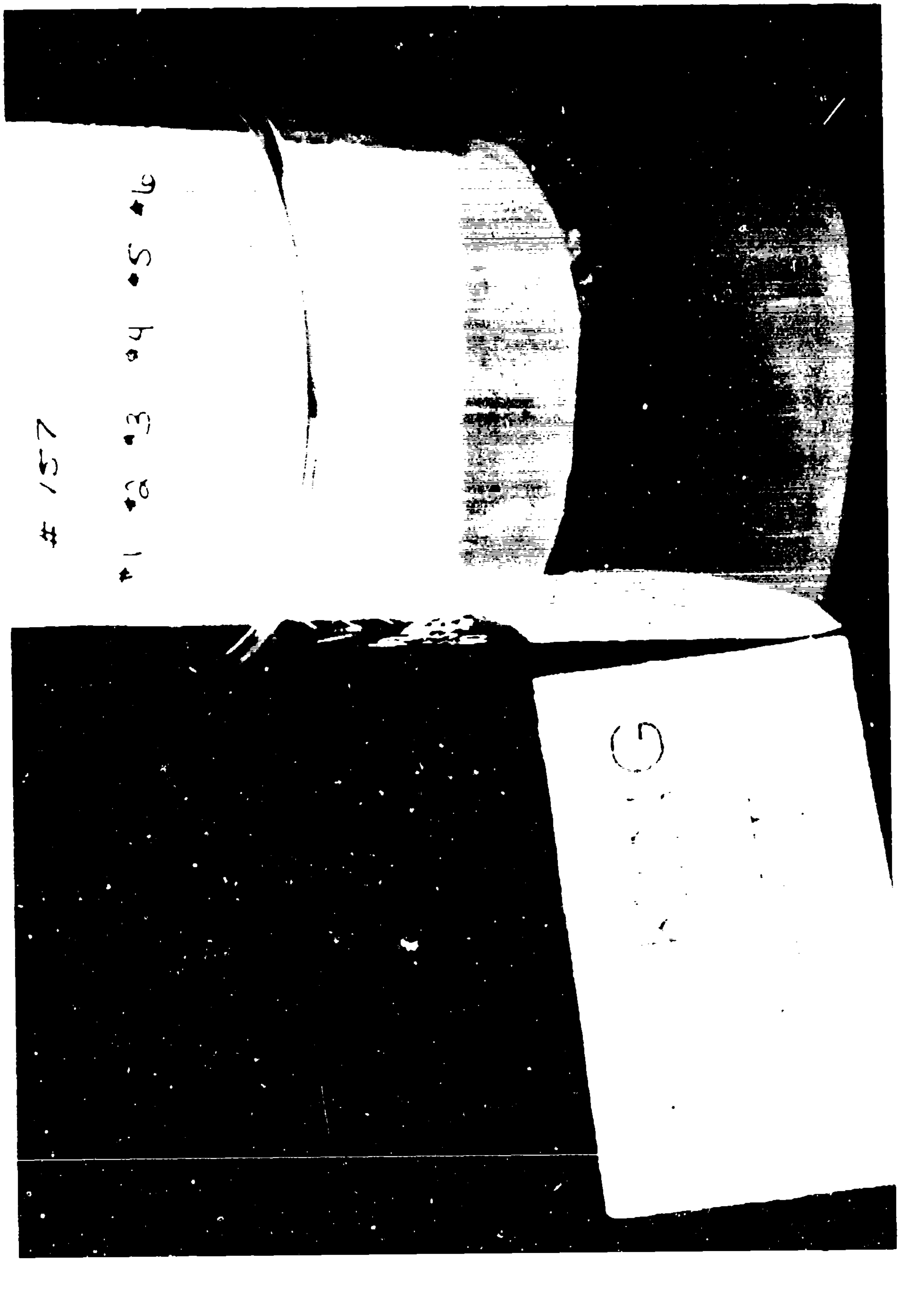


FIGURE 5.48 - WICKING TEST SPECIMENS IN SOLUTION

5.5 MECHANICAL TESTS

5.5.1 ABRASION.

5.5.1.1 Scope: The Abrasion Test provided a relative wear abrasion resistance evaluation of unconditioned wire insulations.

5.5.1.2 Reference Procedure: The Abrasion Test was conducted according to Method 701 of SAE AS4373, which refers to ASTM D09.16, draft 1, dated October 24, 1983. The test was conducted at 150°C (302°F) as well as room ambient.

5.5.1.3 Specimens: The Wear Abrasion Test was conducted on unconditioned samples of 22 gauge, 8.6 mil wall, airframe wire and 22 gauge, 5.8 mil wall, hook up wire. Four specimens of each sample were cut to a length of 12 inches with a quarter inch of insulation removed from both ends and #10 ring terminals crimped on the conductors. The four specimens were placed on the holding block at 0°, 90°, 180°, and 270° from the natural curvature (reel set) of the specimen. Each end of the specimen received a 1.1 pound weight to apply tension. The specimen was centered and clamped into place at both ends of the aluminum test block.

5.5.1.4 Test Equipment: The abrading tool consisted of a 0.020 inch diameter rod silver soldered to a mounting fixture. One tool was secured to each of the two support arms which were counterbalanced to give a tool force of 10 grams when no weights were applied. The test fixture had the ability to be loaded with weights centered above the abrading tool. The arms were attached to an ac motor that moved the tools along a one inch linear path on the specimen at a rate of 60 cycles per minute.

The specimen holding fixture was a block of aluminum which had four 0.026 inch deep "V" grooves for the test specimens. The specimens were placed in the slots with 1.1 lbs. weights attached to the ring terminals. The specimens were centered and clamped into place.

A Delta Design oven (MD 058174) was used at the elevated temperature of 150°C (302°F) with a Fluke Datalogger (MD 084509) to monitor the temperature with a type J thermocouple.

Photographs of the test setup and equipment are presented in Figures 3.18 through 3.21.

5.5.1.5 Test Procedure: The Abrasion Test was conducted until the abrading tool made electrical contact with the wire conductor. The abrading machine was set up to automatically stop when either of the test specimen's insulation was penetrated. The drive rod on the first wire to fail was raised and locked in the up position to

prevent rubbing the abrasion tool on the conductor while the remaining wire was tested to failure.

A calibration test was made at room temperature on each abrasion tool prior to testing each sample of wire. A 3 mil thick sheet of Kapton polyimide tape was wrapped around a 0.375 inch diameter steel rod one layer thick. The abrasion tool rubbed against the Kapton polyimide tape with a two pound weight until continuity was made with the steel rod. The test was conducted at three different spots on the Kapton polyimide tape for each abrasion tool.

The test began with the drive arms locked in the up position and the holding block was placed under the abrading tools. A silicone pad was placed over the specimens and the arms were lowered onto the pad. The pad was used to prevent the abrasion tool from dropping onto the wire when the drive arm locking pin was removed. The tool was raised off the pad, the pad was removed, and the tool was gently lowered onto the test specimen. The test began and ran until both specimens failed. The drive rods were raised and the weight on the tool was changed. The holding fixture was moved forward approximately two inches to an untested spot on the specimen and the test was repeated until all three weights were tested. The drive rods were raised and locked in the up position so that the holding fixture could be rotated 180° to test the remaining two

specimens.

The same procedure was used to test the specimens at ambient as well at 150°C (302°F), except that a temperature stabilization time was not necessary at ambient. The test at the elevated temperature was conducted in a forced draft air oven vented to the outside. A temperature stabilization time was required for the block and specimens to heat up to 150°C (302°F). the abrasion test started approximately 15 minutes after the block achieved the desired temperature of 150°C (302°F). After every subsequent opening of the chamber, the test began one to two minutes after the block recovered to within 2°C of the test temperature.

The number of cycles to failure and the average number of cycles to failure were recorded.

5.5.1.6 Test Results: The results of "0" for the elevated temperature tests indicated that the abrasion tool cut through the insulation as soon as the abrading tool was placed on the wire with the corresponding weight.

The average number of cycles to failure for 1, 2, and 3 pound weights at ambient and 150°C (302°F) are presented in Tables 5.53 through 5.56 with graphical representation of the data presented in Figures 5.49 through 5.56.

TABLE 5.53 - ABRASION TEST RESULTS ON UNCONDITIONED, 22 AWG, 8.6 MIL WALL, AIR FRAME WIRE AT ROOM AMBIENT

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES (1 POUND)	AVERAGE NUMBER OF CYCLES (2 POUND)	AVERAGE NUMBER OF CYCLES (3 POUND)
101	M81381	2493	349	111
106	M22759	180	51	14
136	FILOTEX	1474	89	44
141	TENSOLITE #3	209	16	8
146	THERMATICS #3	2309	152	62
156	NEMA #3	207	33	10

TABLE 5.54 - ABRASION TEST RESULTS ON UNCONDITIONED, 22 AWG, 8.6 MIL WALL, AIR FRAME WIRE AT 150°C (302°F)

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES (1 POUND)	AVERAGE NUMBER OF CYCLES (2 POUND)	AVERAGE NUMBER OF CYCLES (3 POUND)
101	M81381	711	52	18
106	M22759	3	1	0
136	FILOTEX	115	21	6
141	TENSOLITE #3	373	34	7
146	THERMATICS #3	215	70	22
156	NEMA #3	23	8	3

TABLE 5.55 - ABRASION TEST RESULTS ON UNCONDITIONED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE AT ROOM AMBIENT

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES (1 POUND)	AVERAGE NUMBER OF CYCLES (2 POUND)	AVERAGE NUMBER OF CYCLES (3 POUND)
102	M81381	303	57	22
107	M22759	45	19	4
137	FILOTEX	393	61	28
142	TENSOLITE #3	101	10	4
147	THERMATICS #3	320	51	12
157	NEMA #3	56	13	5

TABLE 5.56 - ABRASION TEST RESULTS ON UNCONDITIONED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE AT 150°C (302°F)

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES (1 POUND)	AVERAGE NUMBER OF CYCLES (2 POUND)	AVERAGE NUMBER OF CYCLES (3 POUND)
102	M81381	100	17	6
107	M22759	2	0	0
137	FILOTEX	44	11	2
142	TENSOLITE #3	202	19	9
147	THERMATICS #3	53	19	3
157	NEMA #3	11	3	2

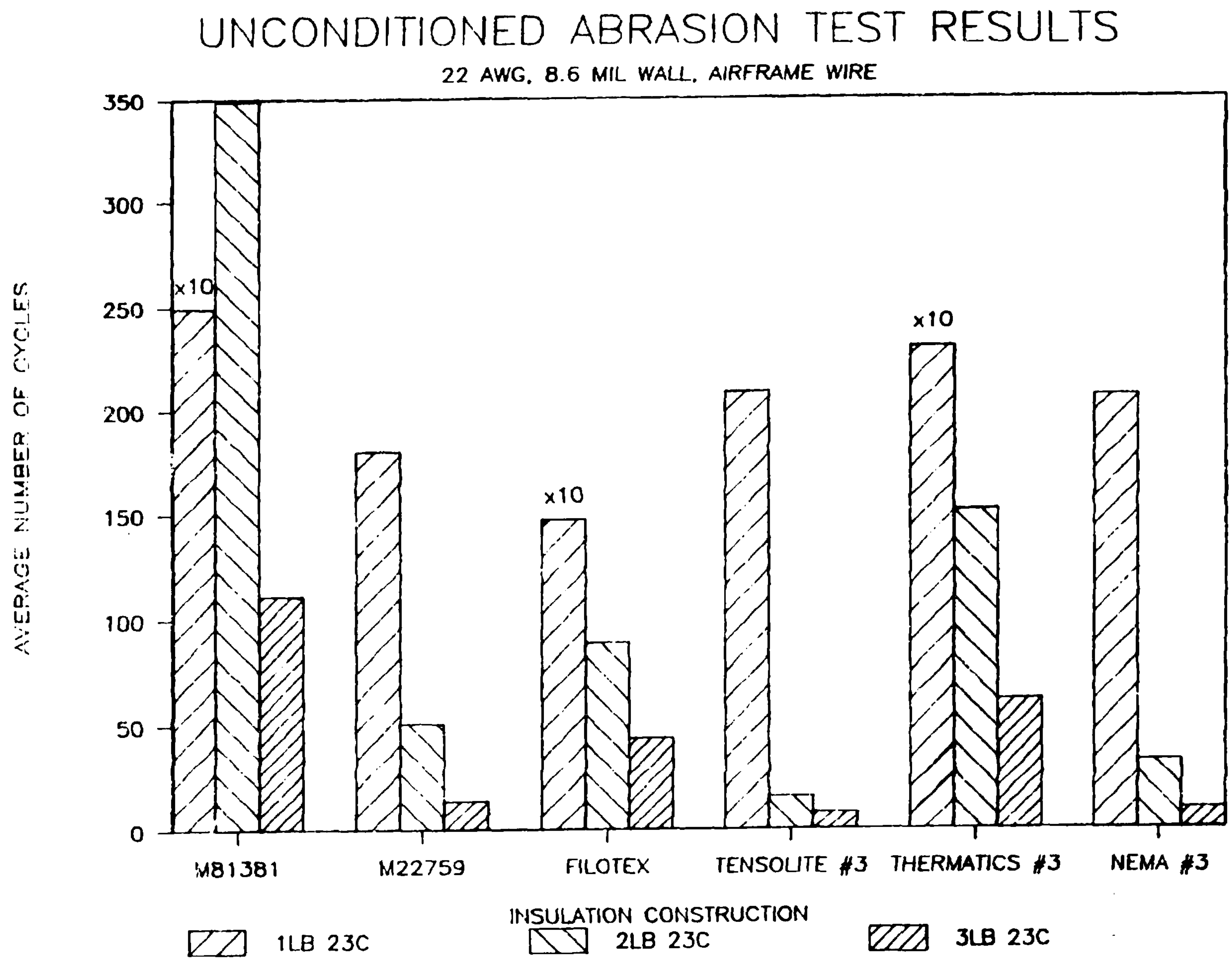


FIGURE 5.49 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 23°C

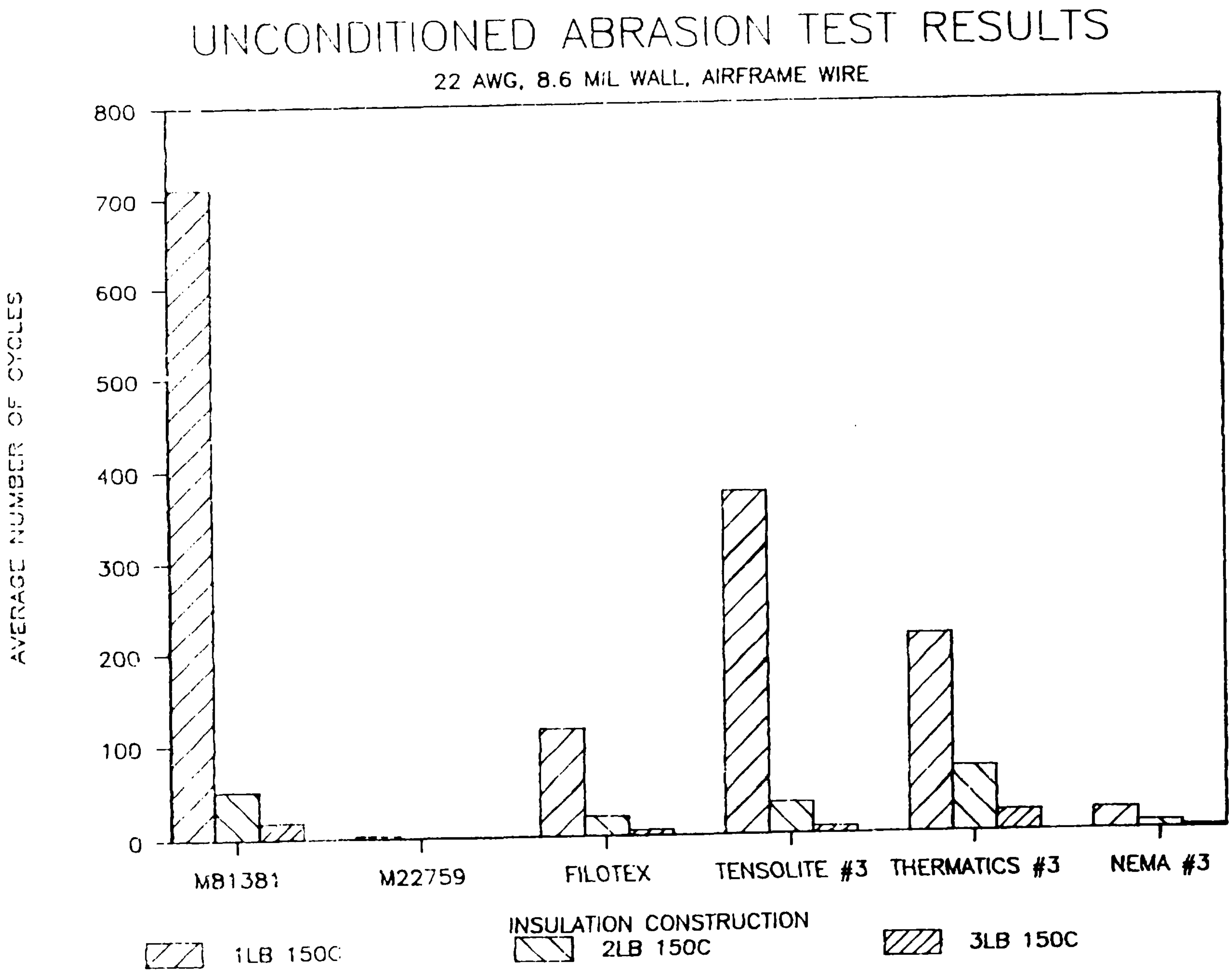


FIGURE 5.50 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 150°C

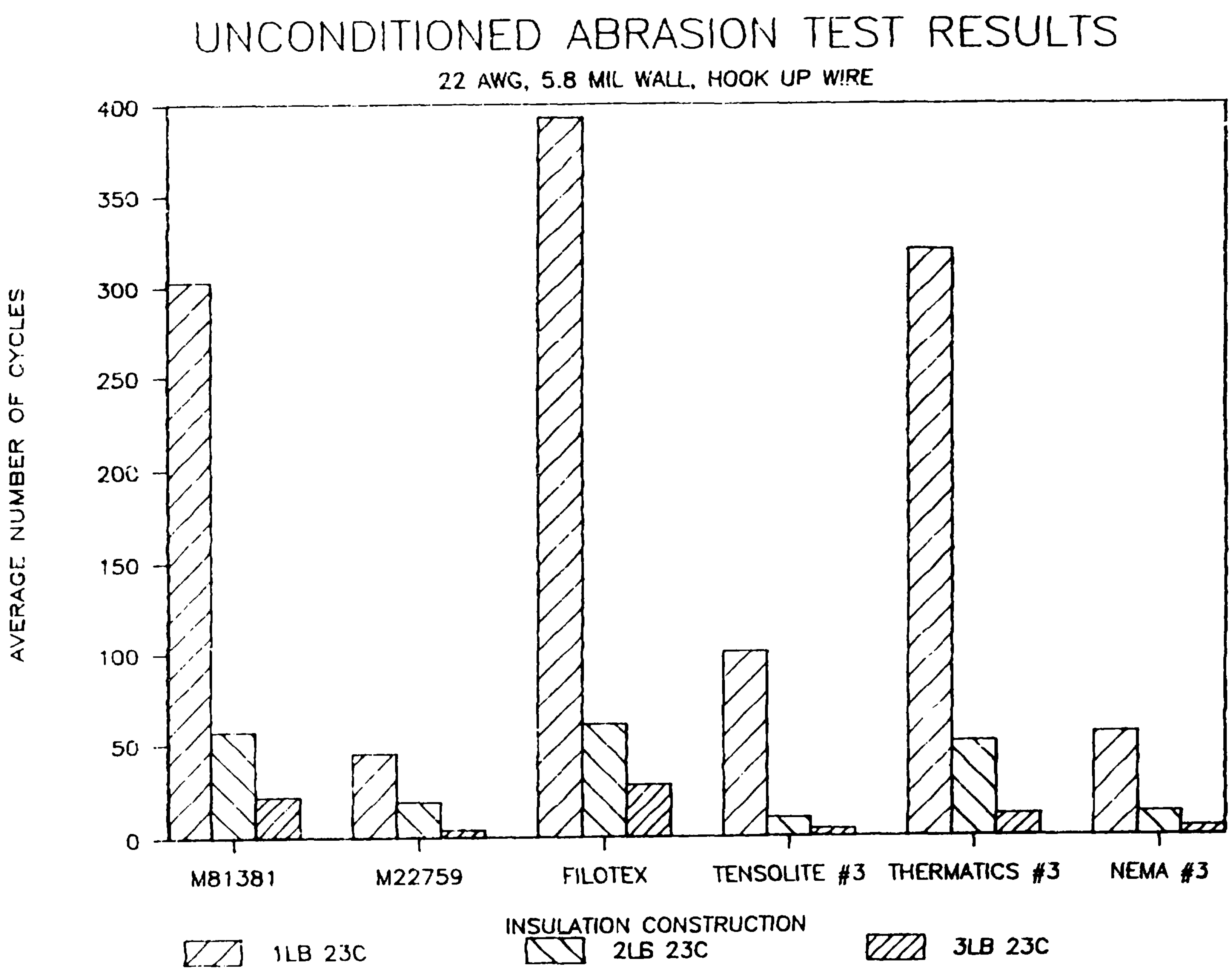


FIGURE 5.51 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 23°C

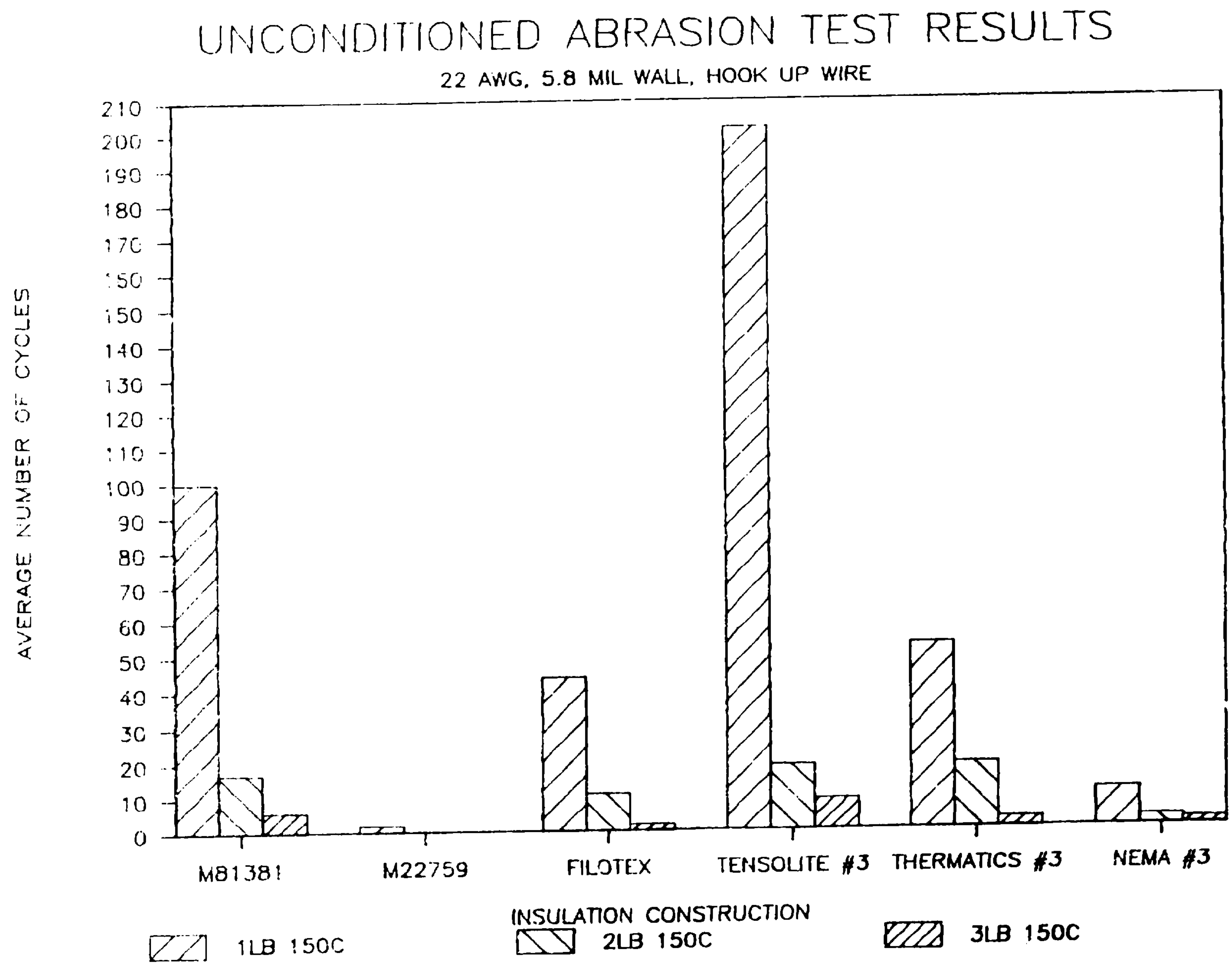


FIGURE 5.52 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 150°C

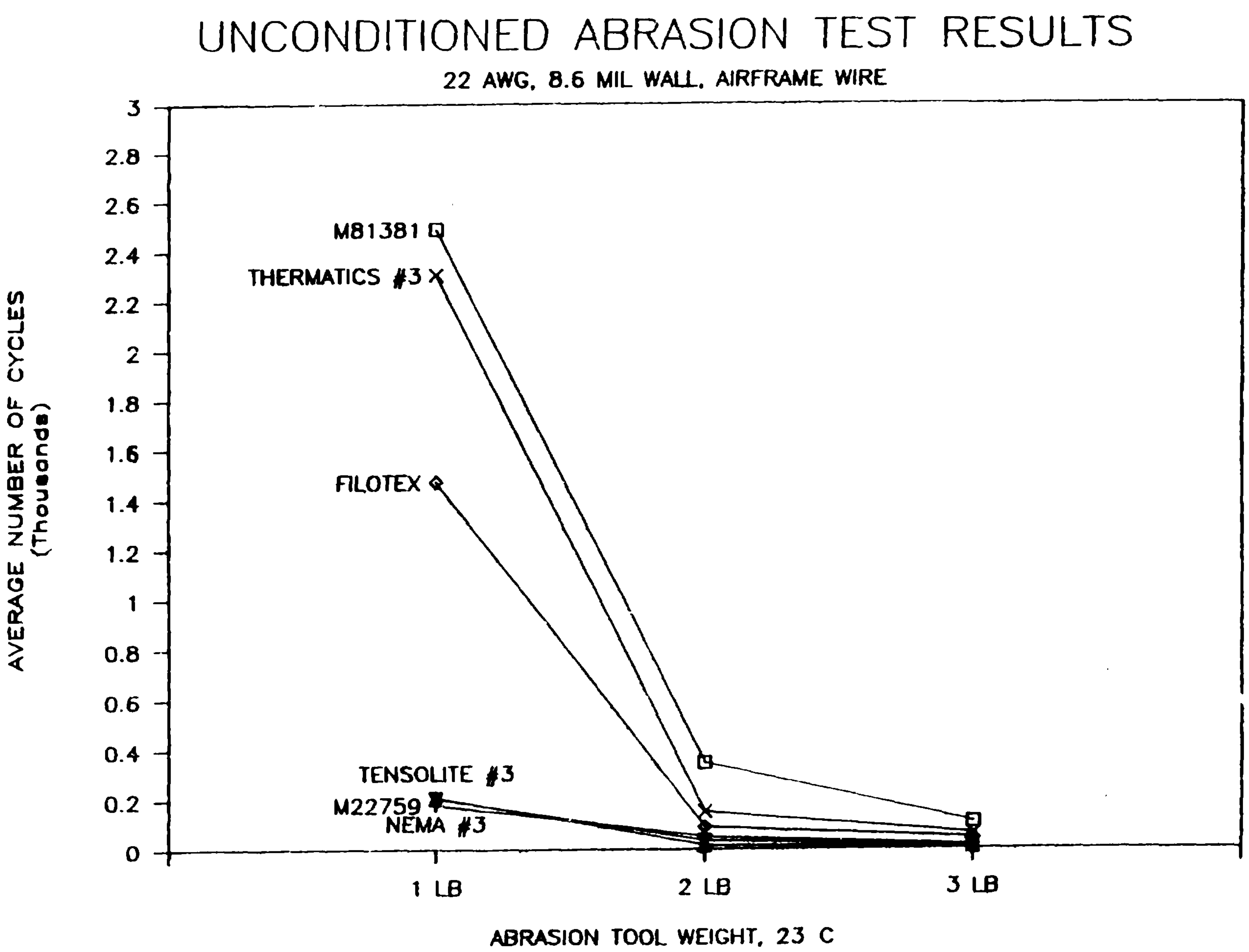


FIGURE 5.53 UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 23°C

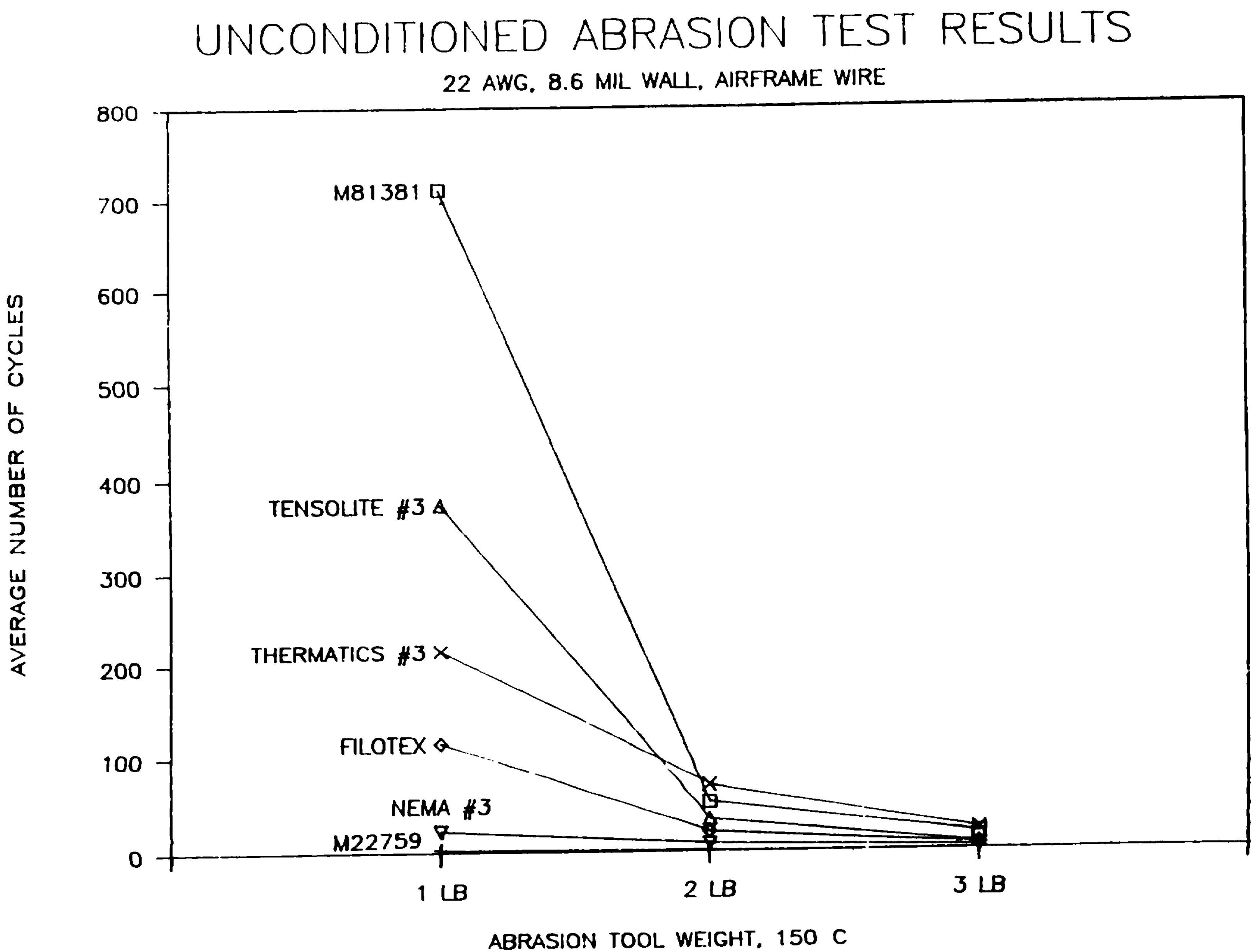


FIGURE 5.54 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 150°C

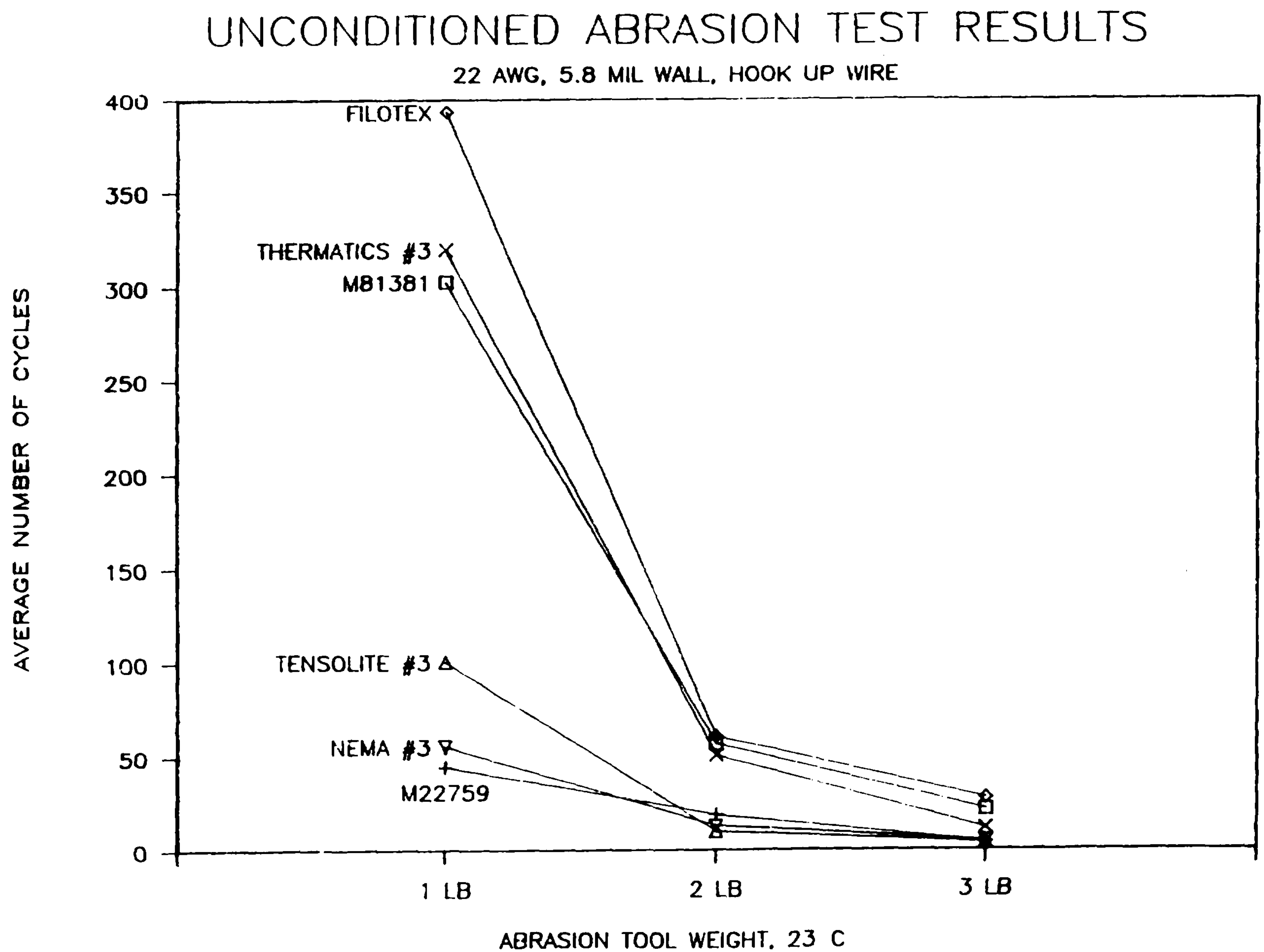


FIGURE 5.55 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 23°C

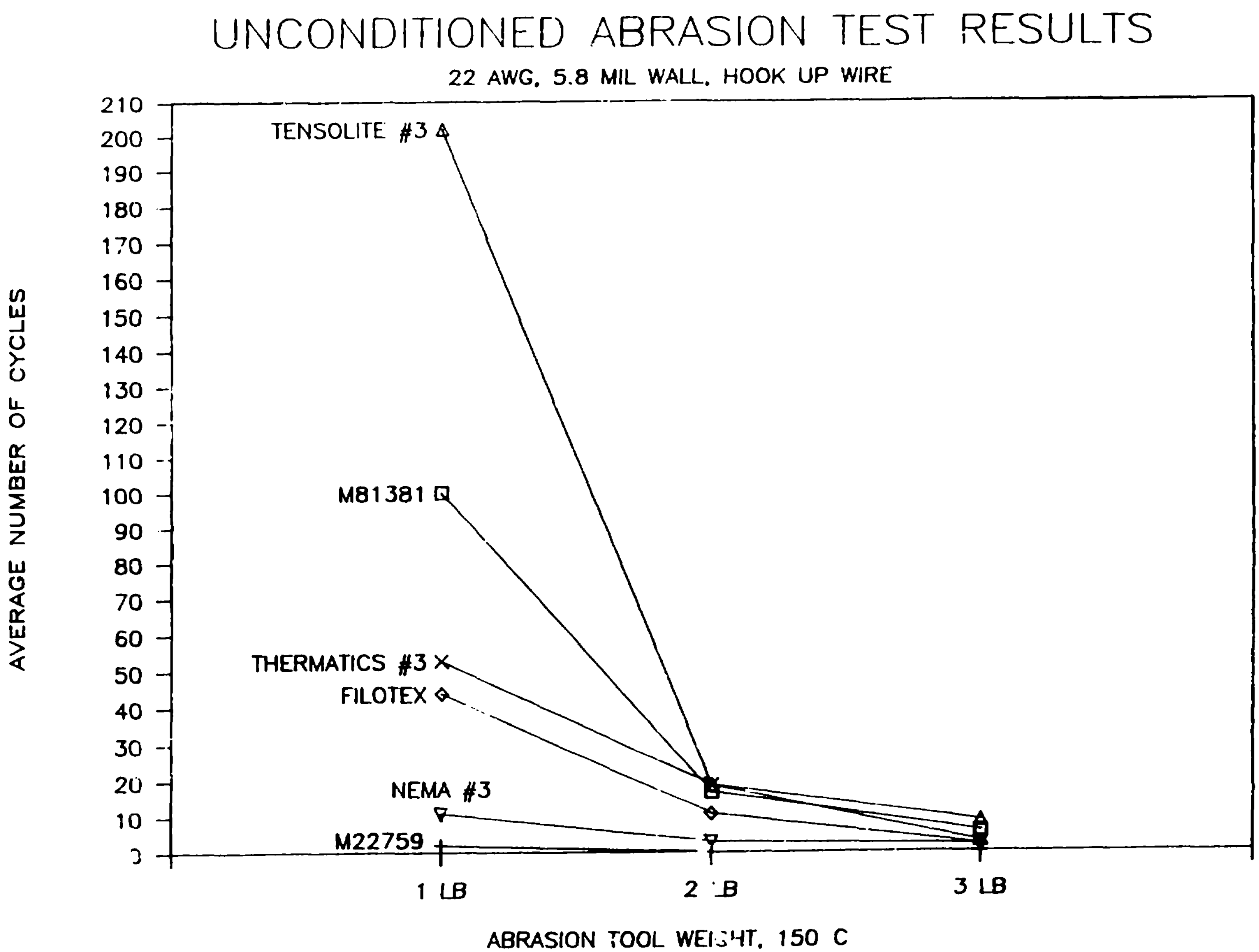


FIGURE 5.56 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 150°C

5.5.2 COLD BEND.

5.5.2.1 Scope: The Cold Bend Test was used to evaluate a wire insulation's or cable jacket's resistance to cracking at low temperatures while being wrapped around a mandrel.

5.5.2.2 Reference Procedure: The Cold Bend Test was conducted according to Method 702 of SAE AS4373. The Cold Bend Test also involved a Voltage Withstand Test, Method 510 of SAE AS4373, to detect failures not detected in the visual inspection.

5.5.2.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 22 gauge, two conductor, twisted, shielded and jacketed cable. Six specimens of each sample were cut to a length of 36 inches.

Wire specimens were prepared by removing a quarter inch of insulation and crimping a #10 ring terminal onto the conductor at each end of the specimen. Cable specimens were prepared by removing an inch of the jacket from both ends of the specimen and the shield was rolled back. A quarter inch of insulation was removed from the primary wires at both ends of the specimen. One end of the cable specimen had #10 ring terminals crimped onto the individual conductors while the opposite end of the

specimen had the two conductors twisted together and crimped into one #10 ring terminal.

5.5.2.4 Test Equipment: A quarter inch thick aluminum cold chamber (31 x 53 x 33 inch), lined with three inch thick Ethafoam, was acquired for the test. The chamber had holes drilled into the side of the chamber to allow access for the manual wrapping of the specimens around the mandrels. The temperature was controlled by a Love Temperature Controller (MD B192208) that regulated the flow from two liquid nitrogen bottles into the chamber. The temperatures were monitored using a Fluke 2190A Digital Thermometer (MD 109893) with type T thermocouples in conjunction with a Fluke 2300A Scanner (MD E040001) and Fluke 2030A Printer for data acquisition.

The specimens were secured to mandrels inside the cold chamber. The mandrels used were 1.0 inch for the 22 gauge, 8.6 mil wall, airframe wire specimens; 0.75 inch for the 22 gauge, 5.8 mil wall, wire specimens; and 2.0 inches for the 22 gauge, two conductor, twisted, shielded and jacketed cable specimens. A 1.0 pound weight was attached to the specimen's ring terminal to apply tension during wrapping. The cable specimens had a 1.0 pound weight placed on each conductor.

A Slaughter 103/105 Dielectric Tester (MD 078995) was used to conduct the Voltage Withstand Test. The voltage was monitored by a Fluke 8050A Digital Multimeter (MD

011821) through a Fluke 80K-6 High Voltage Probe (MD 189698).

Photographs of the test setup and equipment are presented in Figures 5.58 through 5.60.

5.5.2.5 Test Procedure: A set of six, 22 gauge, 8.6 mil wall, wires; 22 gauge, 5.8 mil wall, wires; and 22 gauge, two conductor, twisted, shielded and jacketed cables were secured to their appropriate mandrels. The end of the cable specimen, terminated with only a single ring terminal, was secured to the mandrel. The mandrels with specimens were placed in a holding fixture and placed inside the chamber. The ends of the mandrels were placed through holes in the side of the chamber and a handle was attached. The 1.0 pound weights were attached to the specimen ends and then the specimens were wrapped around the mandrel for one revolution. The mandrels were locked into position. The chamber was sealed and the temperature was lowered to -65±3°C (-85±5°F). The specimens were conditioned at this temperature for a four hour period. At the conclusion of the four hour period, the specimens were wrapped helically around the mandrel for the specimens entire length while still inside the chamber at -65±3°C (-85±5°F). The specimens were wrapped at a rate of 2±1 revolutions per minute. At the completion of the wrapping, the specimens were locked into position by placing pins through the holes in the

mandrels. The liquid nitrogen bottles were turned off and the specimens were allowed to return to room ambient by remaining in the chamber overnight. The chamber was opened and the weights were carefully removed from the specimens before removing the holding fixture from the chamber. The specimens were removed from the mandrels without straightening of the specimen. The insulation was examined for cracks or other anomalies and recorded.

A Voltage Withstand Test was conducted on the wire specimens after completion of the insulation inspection. The wire specimens were tested according to Method 510 of SAE AS4373. The wire specimen's terminals were secured together on a terminal strip. The terminal strip was secured to the container's wall so that the specimens were submerged to within 2.0 inches of their ends in a 5% salt solution (NaCl) with 0.1% wetting agent (Aerosol OT) added. After completion of a four hour soak period, the wire specimens were subjected to 2500 volts at 60 Hertz for one minute. The power was applied between the specimen's conductor and an electrode placed in the solution. A 500 volt per second ramp rate was used to reach 2500 volts. The maximum leakage current observed during the one minute of electrification was recorded unless a failure occurred. If a failure occurred, the time to failure was recorded. A specimen having a leakage current greater than five milliamps was defined as a failure.

The Voltage Withstand Test conducted on the cable specimens followed Method 510 of SAE AS4373, the same procedure as for the wire specimens, except the test voltage used was 1500 volts applied between the shield and the electrode placed in the solution. The maximum leakage current or the time for the specimen to fail was recorded. An additional test was performed that tested the conductors by applying 1500 volts for one minute between the conductors with the shield and electrode tied common. The maximum leakage current was recorded.

At the conclusion of the test, the specimens were rinsed in tap water and air dried before storage.

5.5.2.6 Test Results: One specimen of Tensolite, 22 gauge, two conductor, twisted, shielded and jacketed cable, was damaged when removing the specimen from the cold chamber and is excluded from the test results.

The results from the Bend Test, Voltage Withstand Test, and the average leakage of the specimens passing the Voltage Withstand Test are presented in Tables 5.57 through 5.59 with a graphical representation of the data presented in Figure 5.57.

TABLE 5.57 - COLD BEND TEST RESULTS ON
22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	BEND TEST RESULTS (P / F)	VOLTAGE WITHSTAND RESULTS (P / F)	AVERAGE LEAKAGE CURRENT (MICRO-AMPS)
101	M81381	6 / 0	6 / 0	400
106	M22759	6 / 0	6 / 0	310
136	FILOTEX	6 / 0	6 / 0	250
141	TENSOLITE #3	6 / 0	6 / 0	280
146	THERMATICS #3	6 / 0	6 / 0	593
156	NEMA #3	6 / 0	6 / 0	380

TABLE 5.58 - COLD BEND TEST RESULTS ON
22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	BEND TEST RESULTS (P / F)	VOLTAGE WITHSTAND RESULTS (P / F)	AVERAGE LEAKAGE CURRENT (MICRO-AMPS)
102	M81381	6 / 0	6 / 0	500
107	M22759	6 / 0	6 / 0	412
137	FILOTEX	6 / 0	6 / 0	300
142	TENSOLITE #3	6 / 0	6 / 0	320
147	THERMATICS #3	6 / 0	6 / 0	753
157	NEMA #3	6 / 0	6 / 0	420

TABLE 5.59 - COLD BEND TEST RESULTS ON
22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	BEND TEST RESULTS (P / F)	CONDUCTOR VOLTAGE WITHSTAND RESULTS (P / F)	CONDUCTOR AVERAGE LEAKAGE CURRENT (MICRO-AMP)	SHIELD VOLTAGE WITHSTAND RESULTS (P / F)	SHIELD AVERAGE LEAKAGE CURRENT (MICRO-AMP)
104	M81381	6 / 0	6 / 0	420	6 / 0	650
109	M22759	6 / 0	6 / 0	300	6 / 0	400
139	FILOTEX	6 / 0	6 / 0	300	6 / 0	300
144	TENSOLITE #3	5 / 0	5 / 0	260	5 / 0	396
149	THERMATICS #3	6 / 0	6 / 0	630	6 / 0	433
159	NEMA #3	6 / 0	6 / 0	347	6 / 0	427

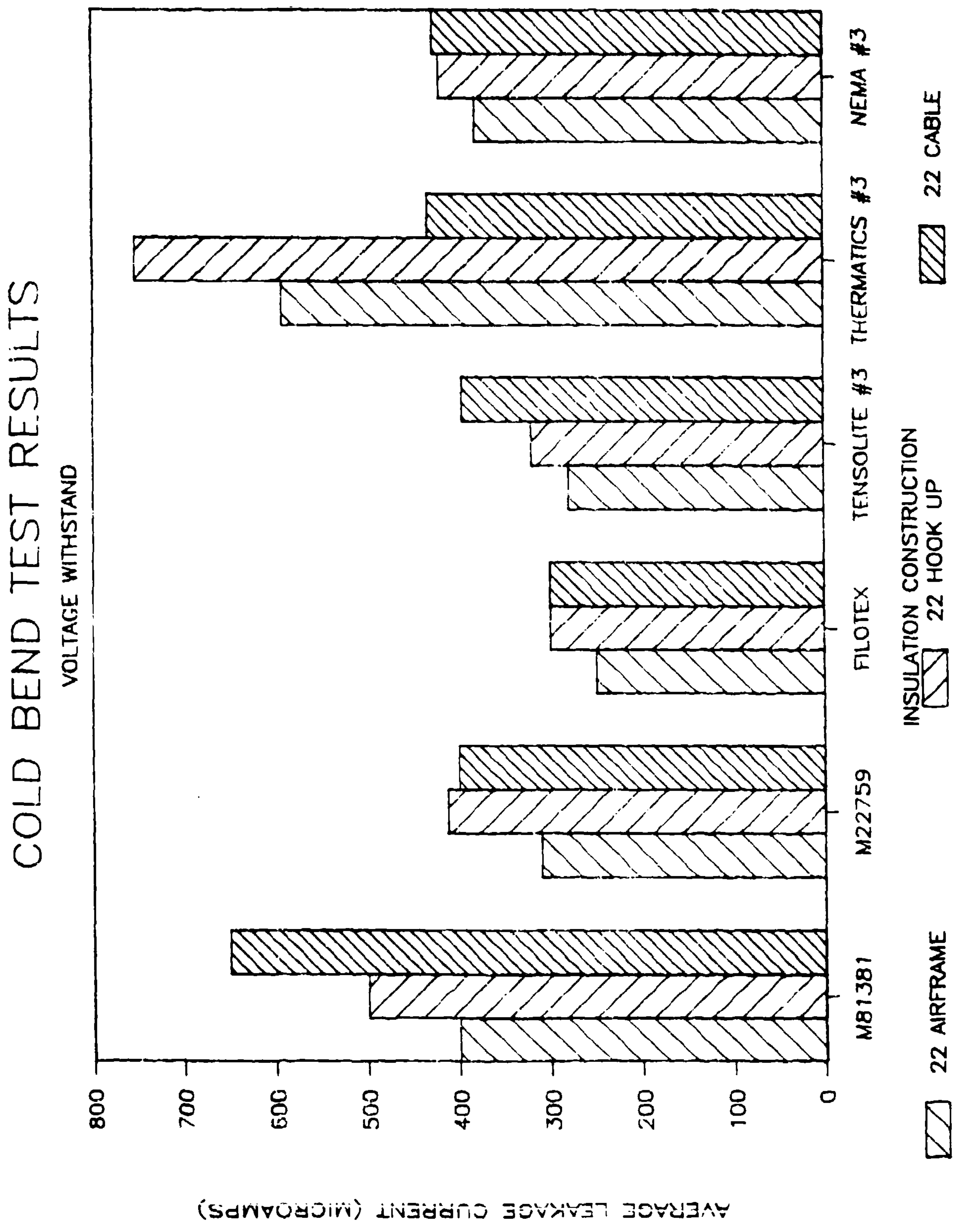


FIGURE 5.57 - COLD BEND TEST RESULTS

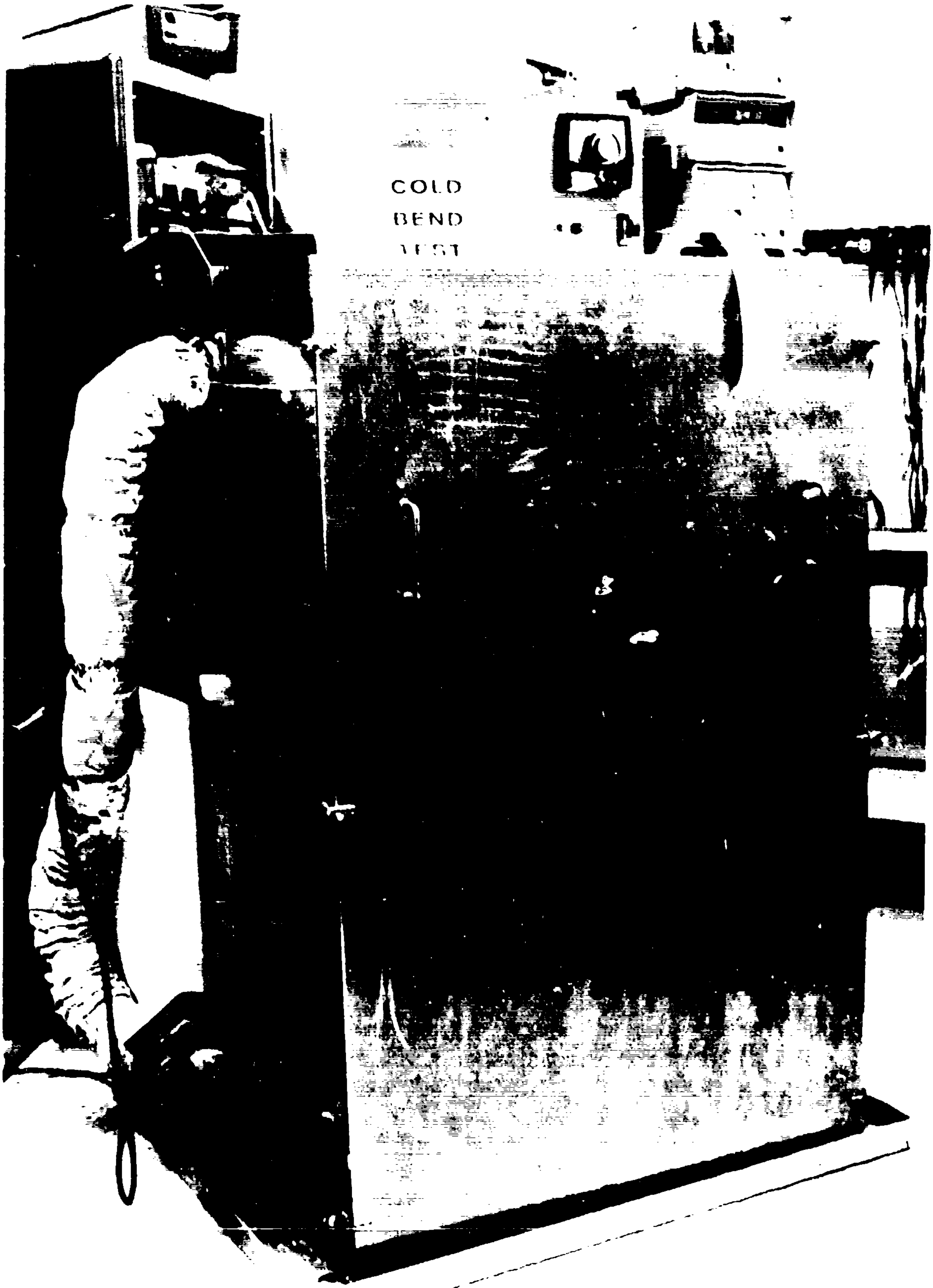


FIGURE 5.58 - COLD BEND TEST SETUP

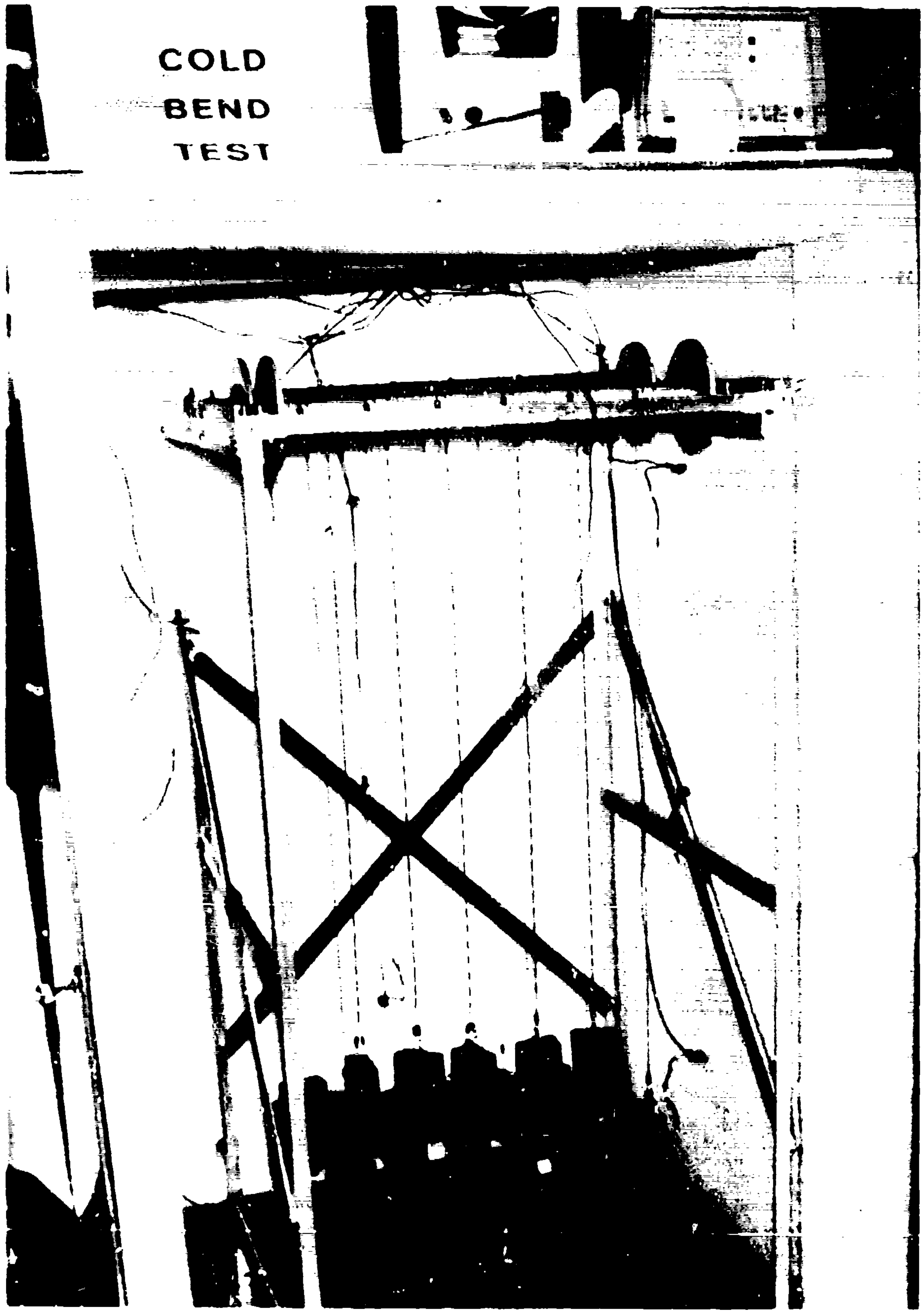


FIGURE 5.59 - COLD BEND TEST CHAMBER

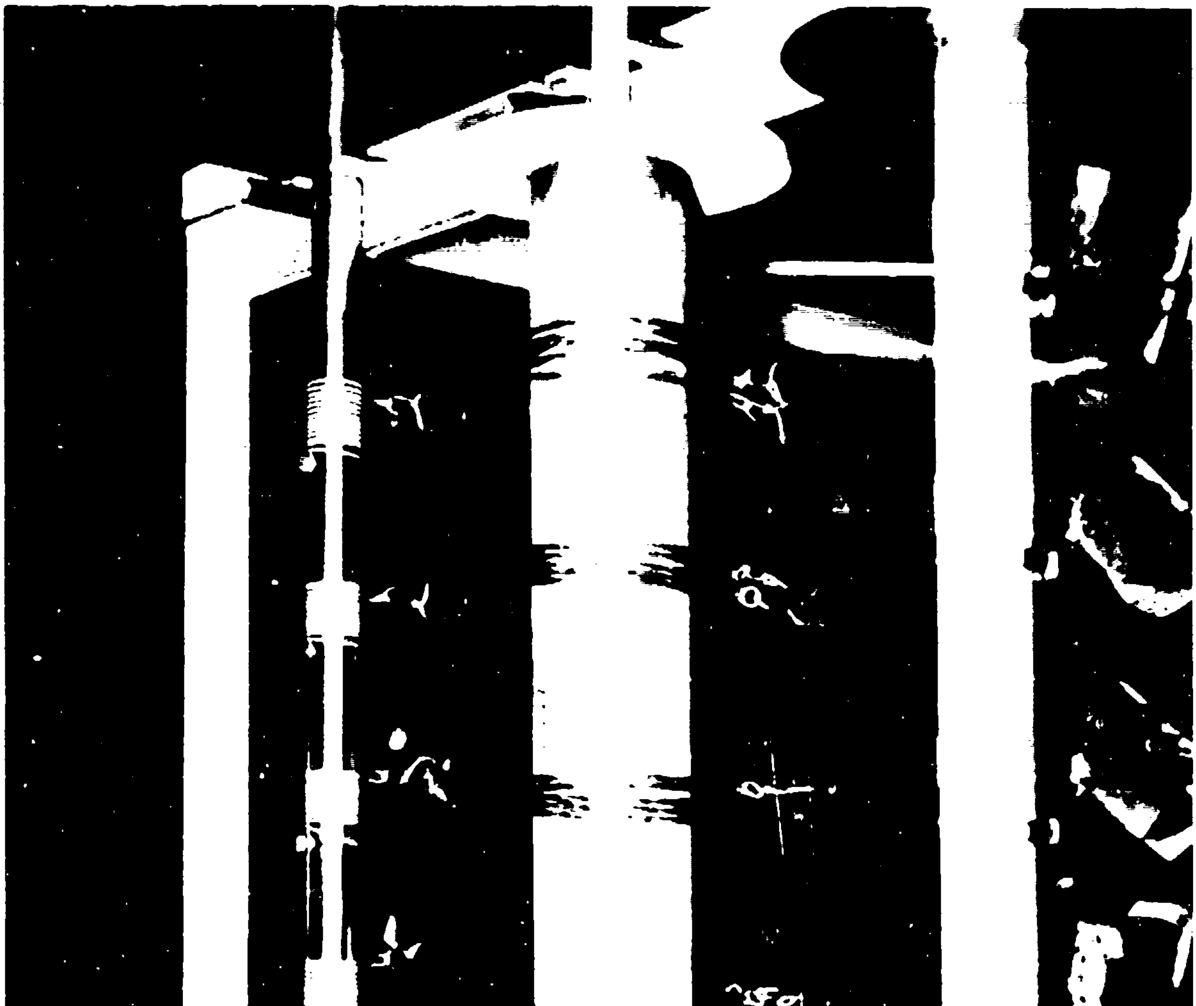


FIGURE 5.60 - COLD BEND TEST RACK

5.5.3 CRUSH RESISTANCE.

5.5.3.1 Scope: The Crush Resistance Test was used to evaluate the ability of an unconditioned wire insulation to withstand a load applied by a flat surface.

5.5.3.2 Reference Procedure: The Crush Resistance Test was performed according to ASTM D3032, Section 20, as no SAE procedure exists.

5.5.3.3 Specimens: Specimens were constructed for 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Eight unconditioned specimens were constructed for each wire sample. The specimens were constructed by being cut into lengths of five inches with a quarter inch of insulation removed from one end.

5.5.3.4 Test Equipment: A Satec 60,000 pound Load Frame (MD 078015) was used with a 60,000 pound load cell to supply the force upon the specimen. A 12 volt dc detection circuit was used to notify the operator to stop the machine after continuity was achieved between the crushing surface and the specimen's conductor. The load cell and volt dc detector circuit were monitored using a Honeywell 1858 CRT Visicorder (MD 090694) to determine the load to failure.

The crushing surface was a flat 2 x 2 inch surface with the two edges parallel to the specimen milled to a 0.25 inch radius.

Photographs of the test setup and equipment are presented in Figures 5.62 through 5.63.

5.5.3.5 Test Procedure: Eight specimens were mounted one inch apart from one another on flat steel plates. The specimens were secured to the base plate using high temperature aluminum tape with two specimens each orientated at 0°, 90°, 180°, and 270° from the natural curvature (reel set) of the wire.

The specimens were placed under the crushing surface and a 12 volt dc detection circuit was connected to detect when continuity between the conductor and the crushing surface had occurred. The crushing surface was pressed against each individual wire at a rate of 0.2 inches per minute until electrical continuity with the conductor was made. The amount of force applied when the insulation was penetrated was recorded on the Visicorder as the point where the detector circuit tripped. The mounting plate was then moved to place a new specimen under the crushing surface and the test was repeated until all eight specimens of each wire sample were tested.

The eight force values were averaged to give an average crush resistance value for that particular wire sample.

5.5.3.6 Test Results: The test results on specimens 141, 142, 156, and 157 were not as expected so a retest was conducted on another set of eight specimens for each sample. The retest confirmed the presented test results.

The average force to penetrate the insulation is presented in Tables 5.60 through 5.62 with a graphical representation of the data is presented in Figure 5.61.

TABLE 5.60 - CRUSH RESISTANCE TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE TO PENETRATE INSULATION (POUNDS)
101	M81381	7468
106	M22759	6714
136	FILOTEX	1195
141	TENSOLITE #3	3813
146	THERMATICS #3	2259
156	NEMA #3	4561

TABLE 5.61 - CRUSH RESISTANCE TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE TO PENETRATE INSULATION (POUNDS)
102	M81381	5570
107	M22759	3668
137	FILOTEX	1100
142	TENSOLITE #3	4404
147	THERMATICS #3	1854
157	NEMA #3	4560

TABLE 5.62 - CRUSH RESISTANCE TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE TO PENETRATE INSULATION (POUNDS)
102	M81381	2381
107	M22759	1385
137	FILOTEX	981
142	TENSOLITE #3	770
147	THERMATICS #3	1345
157	NEMA #3	1295

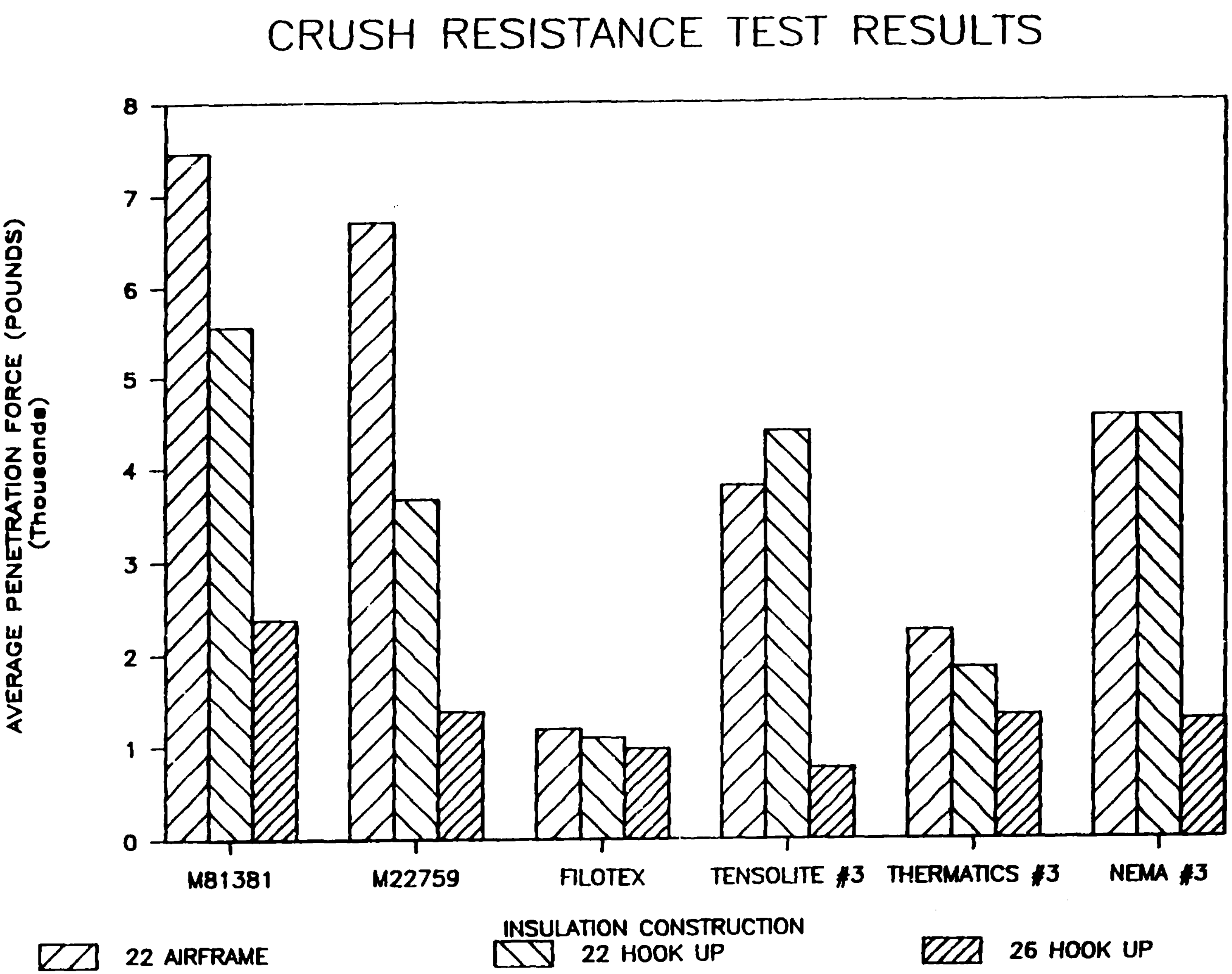


FIGURE 5.61 - *CRUSH RESISTANCE TEST RESULTS*

FIGURE 5.62 - CRUSH RESISTANCE TEST SETUP

FIGURE 5.63 - CRUSH RESISTANCE TEST FIXTURE

5.5.4 DYNAMIC CUT THROUGH.

5.5.4.1 Scope: The Dynamic Cut Through Test was used to evaluate the resistance of the insulation of an unconditioned wire sample to the penetration of a cutting surface.

5.5.4.2 Reference Procedure: The Dynamic Cut Through Test was performed according to Method 703 of SAE AS4373 at 23°C (73°F), 70°C (158°F), 150°C (302°F), and 200°C (392°F) on unconditioned specimens.

5.5.4.3 Specimens: Unconditioned specimens were constructed for 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Eight unconditioned specimens of each sample were constructed for each of the four test temperatures, for a total of 32 specimens. The specimens were cut into lengths of five inches with a quarter inch of insulation removed from one end.

Eight specimens were mounted one inch apart on a 4 x 10 x 0.75 inch flat steel plate with two specimens each orientated at 0°, 90°, 180°, and 270° from the natural curvature (reel set) of the wire. The specimens were secured to the plate using high temperature aluminum tape.

5.5.4.4 Test Equipment: A Satec 60,000 Pound Load Frame (MD 078015) was used with a Revere 500 Pound load cell to supply the force upon the specimen. A 12 volt dc detection circuit was used to notify the operator to stop the machine after continuity was achieved between the cutting tool and the specimen's conductor. The load cell was monitored by a Hewlett-Packard 7047A XY Recorder (MD 079030).

The cutting tool was a 1.5 inch, 20 mil diameter tungsten carbide rod, silver soldered to a holding fixture. The rod had a 4 to 6 micro-inch finish.

An Omega HH-51 Digital Thermometer (MD 202322) with a K type thermocouple was used to measure the elevated temperatures.

Photographs of the test setup and equipment are provided in Figures 3.28 through 3.29.

5.5.4.5 Test Procedure: The specimens were placed under the cutting tool and a 12 volt dc detection circuit was connected to the test specimen. The detection circuit was used to detect continuity between the conductor and the tool. The tool was pressed against one wire at a rate of 0.2 inches per minute until electrical continuity with the conductor was detected. The amount of force applied during the process of penetrating the insulation was recorded on an X-Y recorder. The mounting plate was then moved to place a new specimen under the cutting tool

and the test was repeated until all eight specimens of each wire sample were tested.

The test was repeated at elevated temperatures of 70°C (158°F), 150°C (302°F), and 200°C (392°F). For the elevated temperatures, specimens mounted to the plates were placed in the oven with thermocouples attached to the plates. The test was conducted no earlier than one hour after the plates stabilized at that particular temperature. After opening the chamber door to reposition the test plate, there was a five minute wait to re-stabilize the chamber temperature before the test was conducted on the new specimen.

The eight force values were averaged to acquire an average dynamic cut through value for that particular wire sample and temperature.

5.5.4.6 Test Results: The average force values to penetrate the insulation at 23°C (70°F), 70°C (158°F), 150°C (302°F), and 200°C (392°F) are presented in Tables 5.63 through 5.65 with graphical representation of data provided in Figures 5.64 through 5.69.

TABLE 5.63 - DYNAMIC CUT THROUGH TEST RESULTS ON UNCONDITIONED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE AT 23°C (POUNDS)	AVERAGE FORCE AT 70°C (POUNDS)	AVERAGE FORCE AT 150°C (POUNDS)	AVERAGE FORCE AT 200°C (POUNDS)
101	M81381	78.5	76.4	61.6	54.6
106	M22759	57.0	46.3	8.9	3.0
136	FILOTEX	40.6	29.1	16.4	10.0
141	TENSOLITE #3	29.5	32.8	25.1	30.5
146	THERMATICS #3	43.0	40.6	37.5	36.8
156	NEMA #3	54.8	36.9	41.8	31.4

TABLE 5.64 - DYNAMIC CUT THROUGH TEST RESULTS ON UNCONDITIONED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE AT 23°C (POUNDS)	AVERAGE FORCE AT 70°C (POUNDS)	AVERAGE FORCE AT 150°C (POUNDS)	AVERAGE FORCE AT 200°C (POUNDS)
102	M81381	65.0	59.4	50.0	41.8
107	M22759	29.4	22.0	3.1	2.1
137	FILOTEX	37.8	36.3	19.0	12.5
142	TENSOLITE #3	28.9	43.3	25.3	23.0
147	THERMATICS #3	33.6	25.1	33.3	30.4
157	NEMA #3	53.0	28.6	38.6	32.3

TABLE 5.65 - DYNAMIC CUT THROUGH TEST RESULTS ON UNCONDITIONED, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE AT 23°C (POUNDS)	AVERAGE FORCE AT 70°C (POUNDS)	AVERAGE FORCE AT 150°C (POUNDS)	AVERAGE FORCE AT 200°C (POUNDS)
103	M81381	49.8	44.3	27.0	15.6
108	M22759	26.5	17.6	3.8	4.1
138	FILOTEX	22.1	17.9	9.3	12.5
143	TENSOLITE #3	9.8	22.1	9.3	7.6
148	THERMATICS #3	21.1	14.5	14.3	9.0
158	NEMA #3	14.9	10.5	5.8	4.5

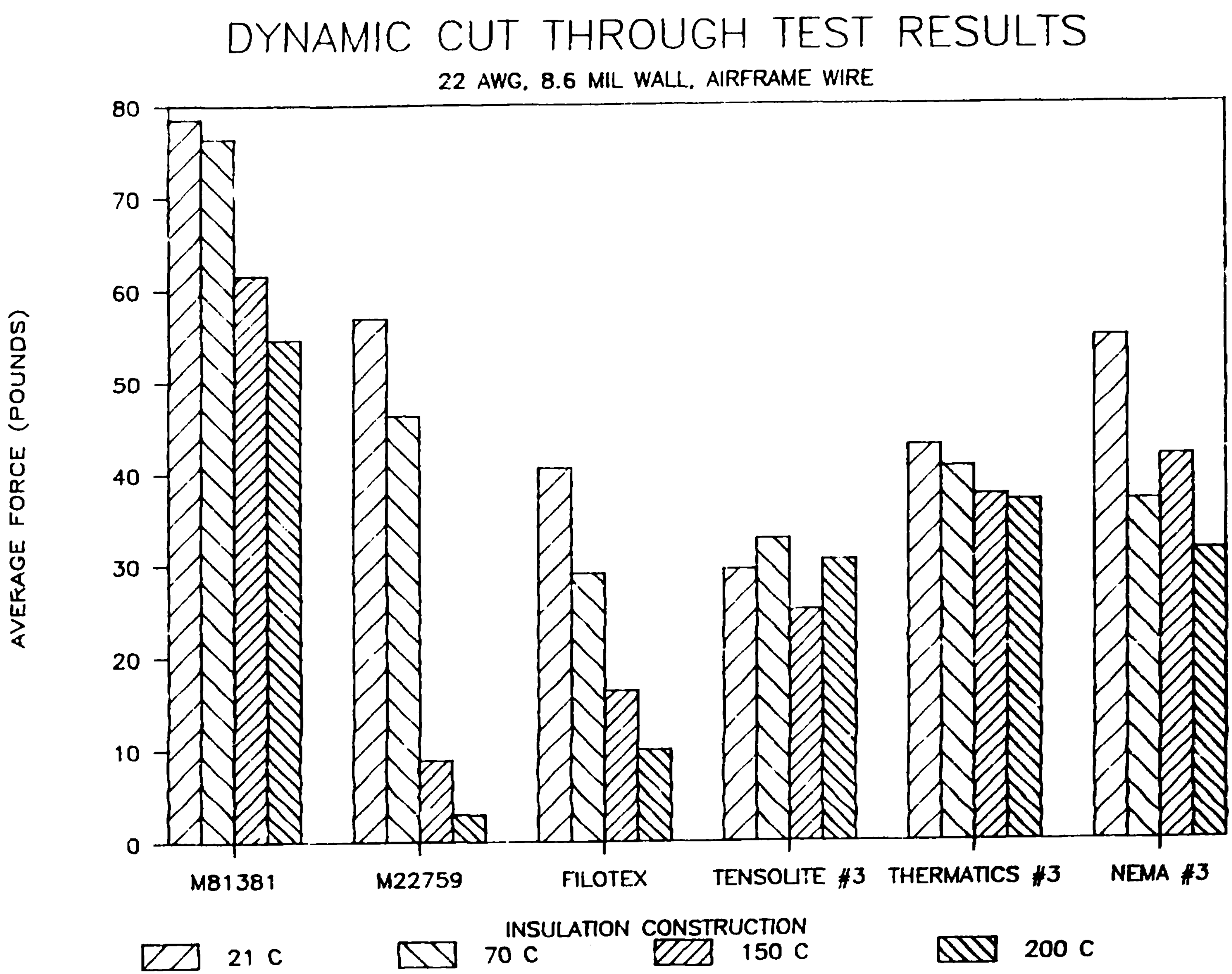


FIGURE 5.64 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

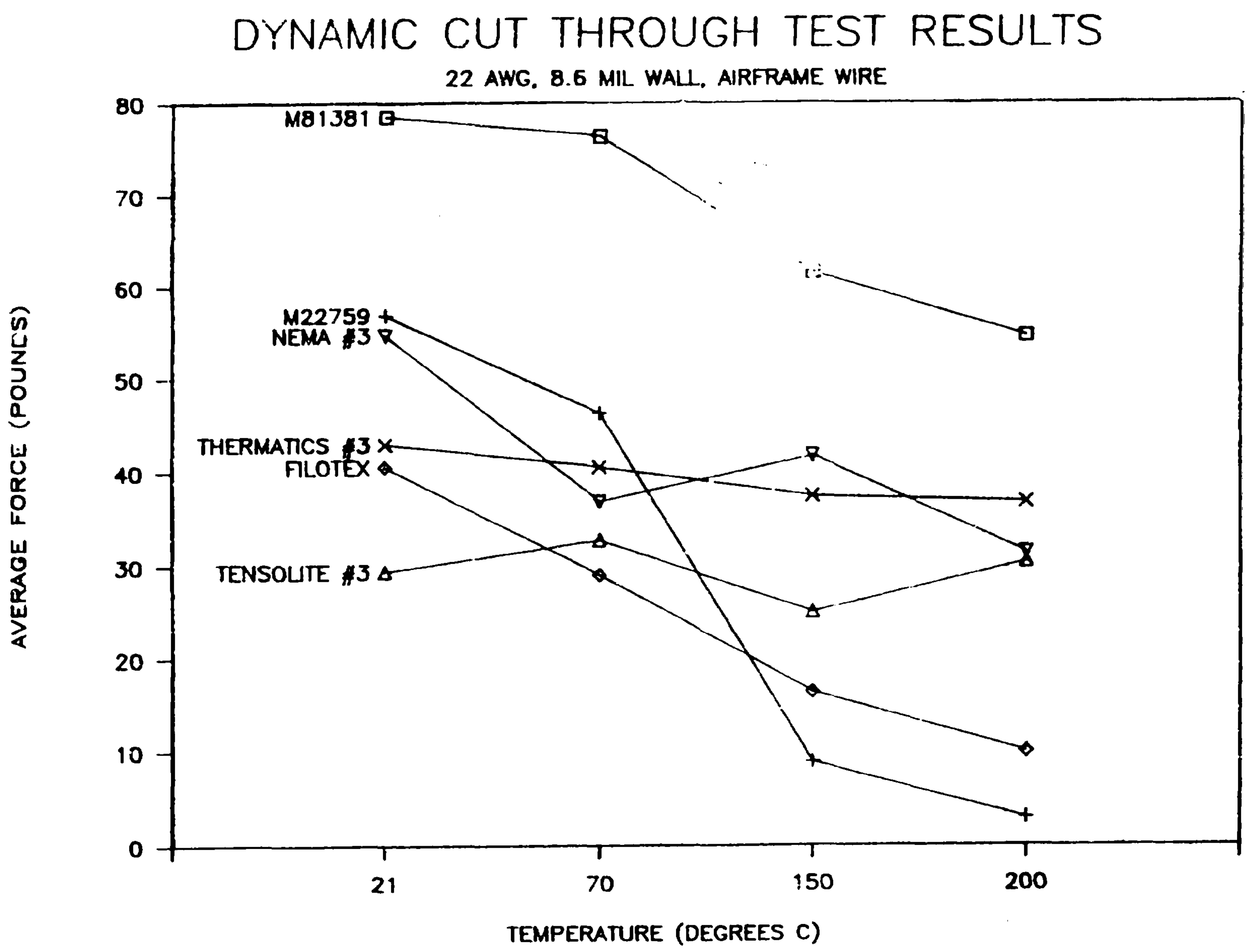


FIGURE 5.65 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

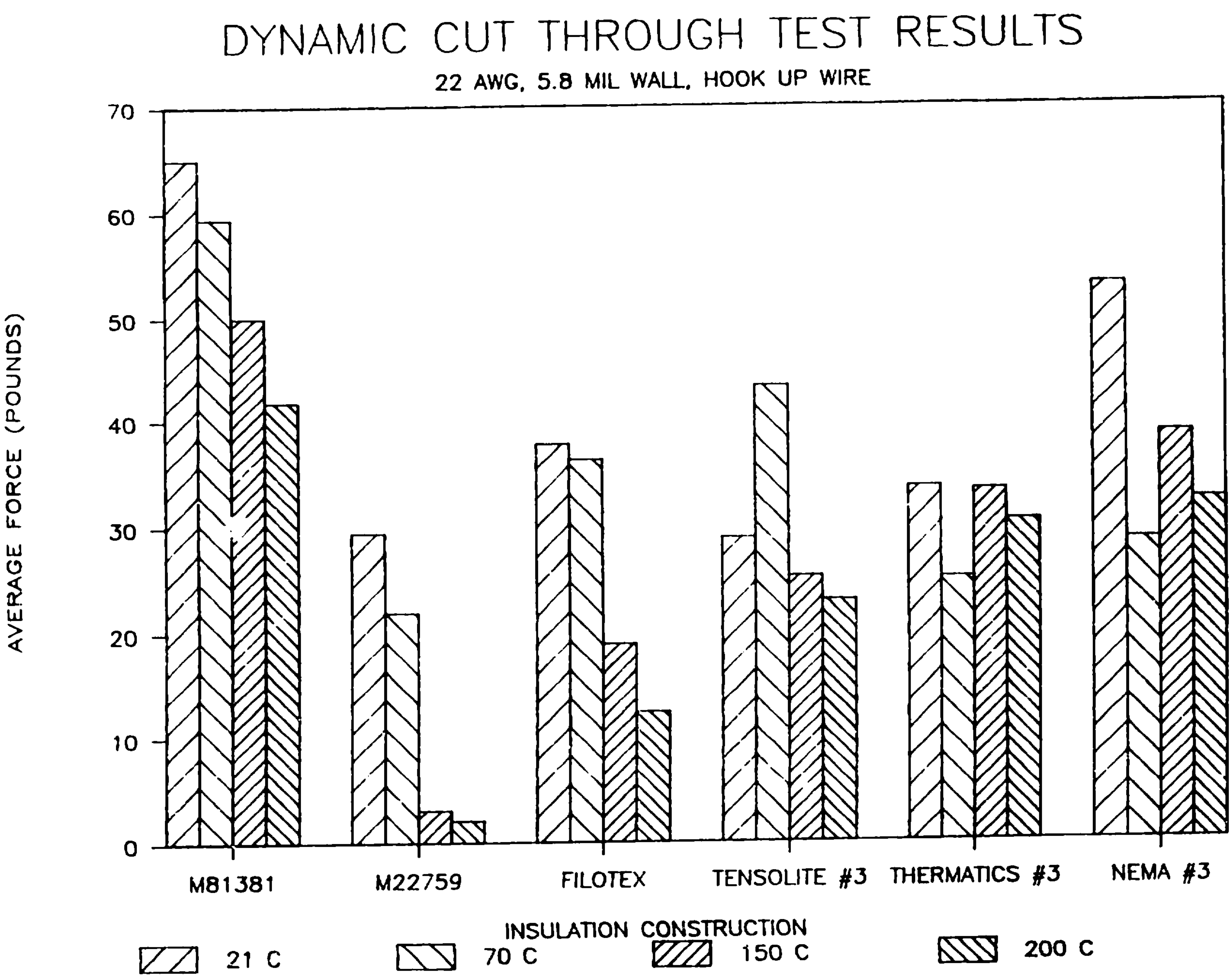


FIGURE 5.66 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

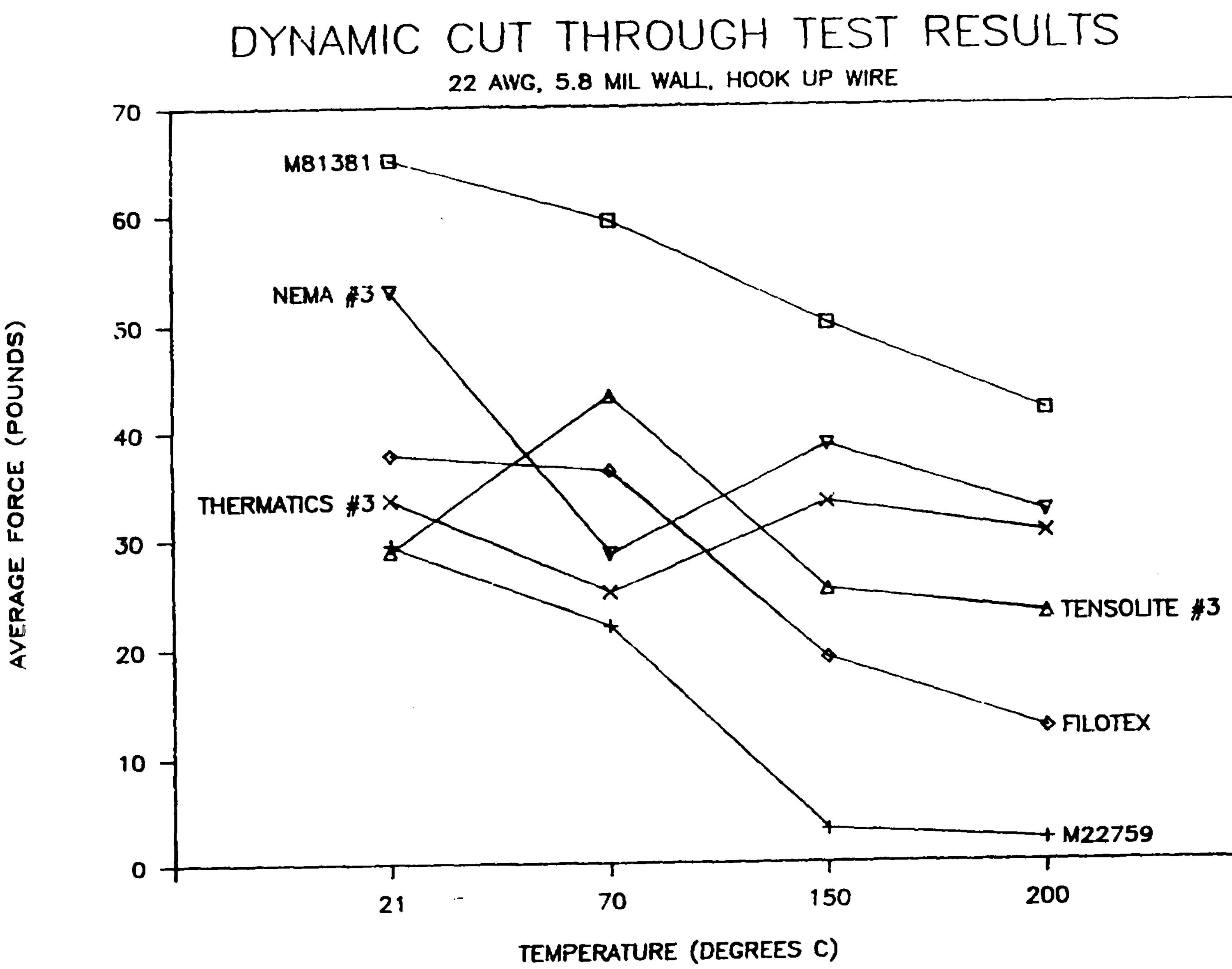


FIGURE 5.67 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

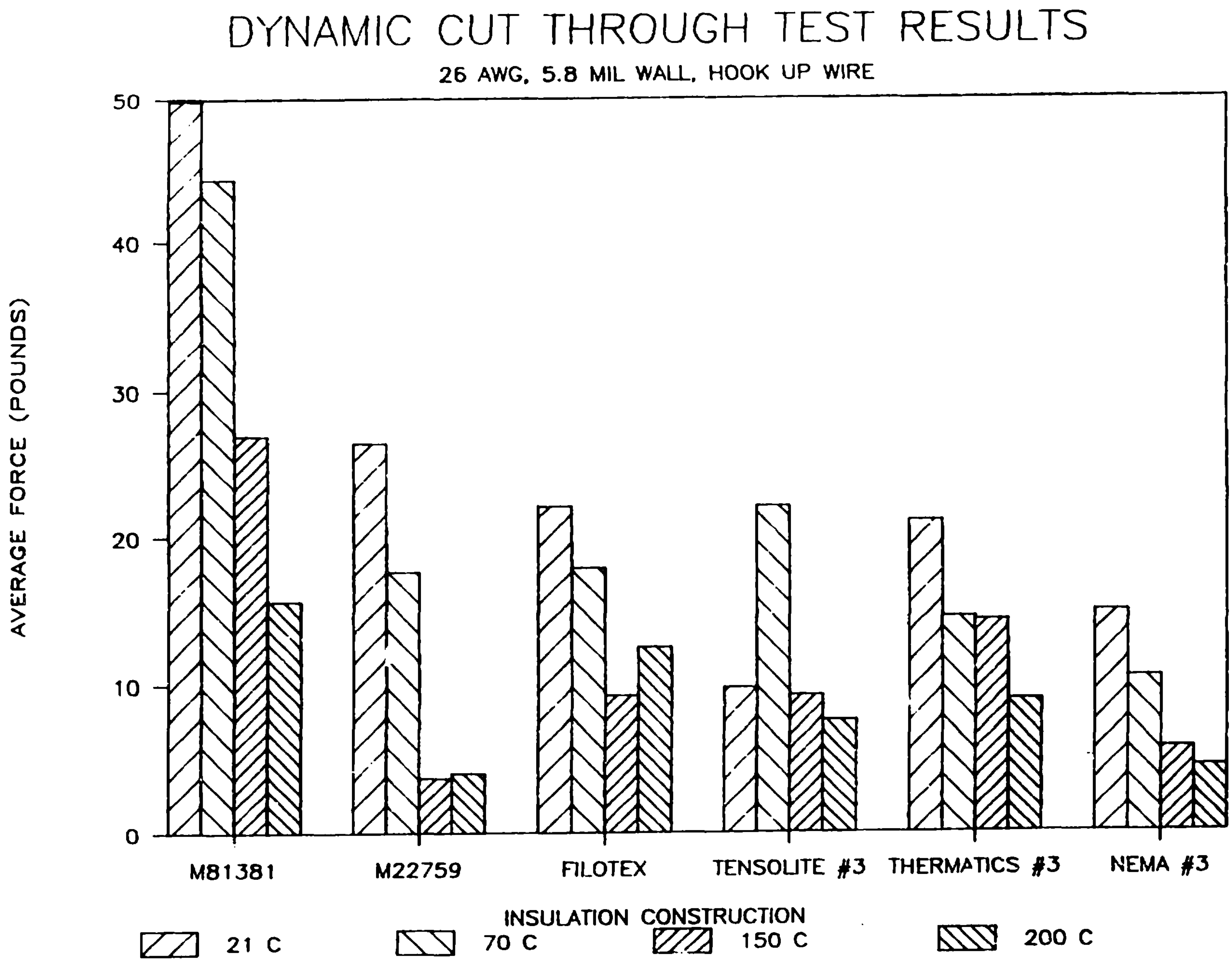


FIGURE 5.68 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

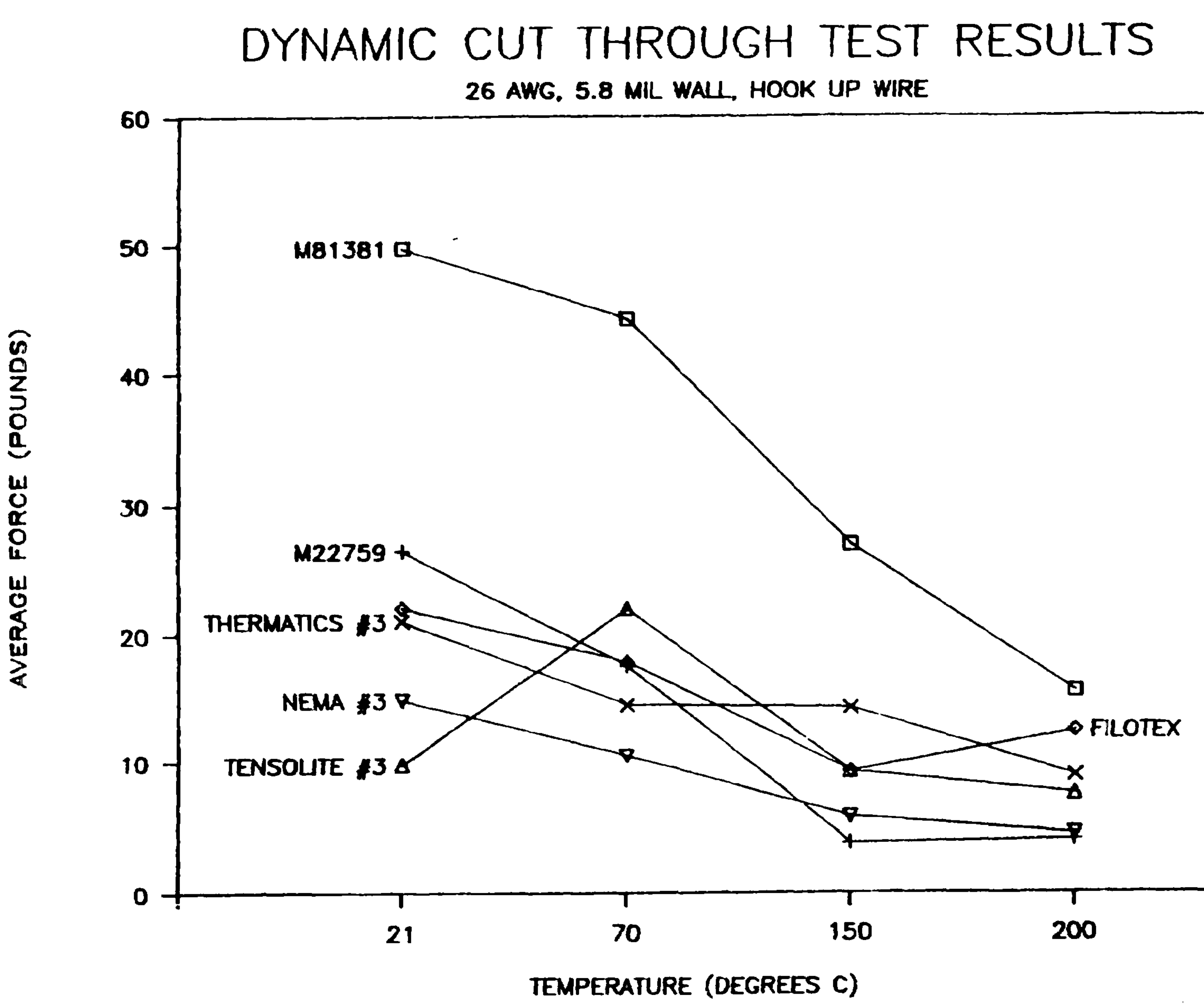


FIGURE 5.69 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

5.5.5 FLEX LIFE.

5.5.5.1 Scope: The Flex Life Test was used to determine the mechanical flex strength of the conductor and insulation as a system.

5.5.5.2 Reference Procedure: The Flex Life test was conducted according to Paragraph 3.9.6 of SAE AS4373, dated 15 May 1987, with the following modifications. The weight used to apply tension was 20% of the conductor's break strength. A failure of the wire specimens was defined as a 115% increase in the conductor's resistance or a crack in the insulation so as to observe the conductor at the crack. Failures on shielded and jacketed cable specimens were defined as 115% increase in the resistance of the shield or cracking of the jacket to visually observe the shield at the crack.

5.5.5.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; 26 gauge, 5.8 mil wall, hook up wire; 22 gauge, two conductor, twisted, shielded and jacketed cable; and 26 gauge, two conductor, twisted, shielded and jacketed cable. Six unconditioned specimens were cut to a length of 18 inches from each sample.

For wire specimens, a half inch of insulation was removed and a spade lug was crimped on the conductor at

one end to attach the specimen to the flexing arm. The other end of the specimen had approximately two inches of insulation removed with no damage to the conductor strands. A nine inch instrumentation lead was crimped on the conductor using a crimp splice (ST5M1345-002) approximately 1.5 inches from the end of the specimen. This lead monitored the conductor's resistance. A 12 inch instrumentation lead and the conductor end were crimped together in a #10 ring terminal to support a weight and hold the specimen taut during flexing.

For cable specimens, an inch and a half of the jacket was removed from one end and the shield rolled back so that a three inch instrumentation lead could be connected to the shield by a solder splice. The two wires at that end had a half inch of insulation removed and spade lugs were crimped on each conductor for attachment to the flexing arm. A three inch segment of the jacket was removed from the opposite end of the specimen. Approximately 1.5 inches of the shield was removed and the remaining 1.5 inches was pushed back and attached to a 12 inch instrumentation lead by use of a solder splice. This lead monitored the shield's resistance. Two inches of insulation was removed from each of the wires without damaging the conductor. A nine inch instrumentation lead was crimped on each conductor using crimp splices (ST5M1345-002) approximately 1.5 inches from the end of the conductors. These leads monitored the individual

conductor's resistance. Twelve inch instrumentation leads were crimped together with the conductors in #10 ring terminals to attach weights to hold the cable taut during flexing.

5.5.5.4 Test Equipment: A Daytronics Data Acquisition System (MD 122188) with appropriate input/output cards was used to monitor the resistance of the specimens and record the number of cycles for a 115% increase in resistance. Mandrels were required that were approximately six times the outer diameter of the specimen being flexed. The mandrel diameters used were 0.28 inch for the 22 gauge, 8.6 mil wall, airframe wires; 0.25 inch for the 22 gauge, 5.8 mil wall, hook up wires; 0.19 inch for the 26 gauge, 5.8 mil wall, hook up wires; 0.624 inch for the 22 gauge, two conductor, twisted, shielded and jacketed cables; and 0.5 inch for the 26 gauge, two conductor, twisted, shielded and jacketed cables. The mandrels were covered with one layer of 5 mil Teflon tape. This tape, which was used to reduce friction, was replaced for each new set of test specimens.

A four pound weight, representing 20% of the conductor break strength, was applied to the 22 and 26 gauge conductors to apply tension during flexing. For cable specimens, one four pound weight was applied to each conductor.

Photographs of the test setup and equipment are presented in Figures 3.31 through 3.32.

5.5.5.5 Test Procedure: Three wires or two cable specimens were clamped to a pivoting arm six inches above a pair of the appropriate mandrels. Spacers one to two mils thick were placed, one on each end, in between the mandrel openings. The mandrels were adjusted until snug against both spacers and the spacers were then removed. The mandrels were adjusted so that a two mil spacer would pass between the mandrel and the specimen but a three mil would not. Guides were placed by the weights to prevent weight swing during the test.

The specimens were flexed 90° from vertical in one direction, back to vertical, 90° from vertical in the opposite direction, and back to vertical for one cycle. The flex arm was cycled at a rate of 30 cycles per minute until a 115% resistance increase failure occurred or a crack in the insulation occurred that made the conductor or shield visible.

5.5.5.6 Test Results: The average number of cycles to failure and the types of failures encountered are presented in Tables 5.66 through 5.70 with graphical representation of the data presented in Figures 5.70 through 5.71.

TABLE 5.66 - FLEX LIFE TEST RESULTS ON UNCONDITIONED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	QUANTITY PER TYPE OF FAILURE: 115% INCREASE CONDUCTOR RESISTANCE	CRACK IN INSUL. OBSERVED CONDUCTOR	SPECIMEN BROKE AT FLEXING POINT
101	M81381	1663	6	0	0
106	M22759	180	6	0	0
136	FILOTEX	117	3	0	3
141	TENSOLITE #3	246	6	0	0
146	THERMATICS #3	72	0	0	6
156	NEMA #3	595	0	0	6

TABLE 5.67 - FLEX LIFE TEST RESULTS ON UNCONDITIONED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	QUANTITY PER TYPE OF FAILURE: 115% INCREASE CONDUCTOR RESISTANCE	CRACK IN INSUL. OBSERVED CONDUCTOR	SPECIMEN BROKE AT FLEXING POINT
102	M81381	637	0	0	6
107	M22759	78	2	0	4
137	FILOTEX	91	2	0	4
142	TENSOLITE #3	131	4	0	2
147	THERMATICS #3	58	0	0	6
157	NEMA #3	237	2	0	4

TABLE 5.68 - FLEX LIFE TEST RESULTS ON UNCONDITIONED, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	QUANTITY PER TYPE OF FAILURE: 115% INCREASE CONDUCTOR RESISTANCE	CRACK IN INSUL. OBSERVED CONDUCTOR	SPECIMEN BROKE AT FLEXING POINT
103	M81381	949	2	0	4
108	M22759	90	0	0	6
138	FILOTEX	35	6	0	0
143	TENSOLITE #3	82	0	0	6
148	THERMATICS #3	105	0	0	6
158	NEMA #3	643	1	0	5

TABLE 5.69 - FLEX LIFE TEST RESULTS ON UNCONDITIONED, 22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

			QUANTITY PER TYPE OF FAILURE		
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	115% INCREASE SHIELD RESISTANCE	CRACK IN JACKET OBSERVED SHIELD	SPECIMEN BROKE AT FLEXING POINT
104	M81381	108	0	6	0
109	M22759	285	6	0	0
239	FILOTEX	413	6	0	0
144	TENSOLITE #3	2102	6	0	0
149	THERMATICS #3	248	6	0	0
159	NEMA #3	400	5	1	0

TABLE 5.70 - FLEX LIFE TEST RESULTS ON UNCONDITIONED, 26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

			QUANTITY PER TYPE OF FAILURE		
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	115% INCREASE SHIELD RESISTANCE	CRACK IN JACKET OBSERVED SHIELD	SPECIMEN BROKE AT FLEXING POINT
105	M81381	124	0	6	0
110	M22759	287	6	0	0
240	FILOTEX	399	6	0	0
145	TENSOLITE #3	1625	5	1	0
150	THERMATICS #3	541	6	0	0
160	NEMA #3	986	6	0	0

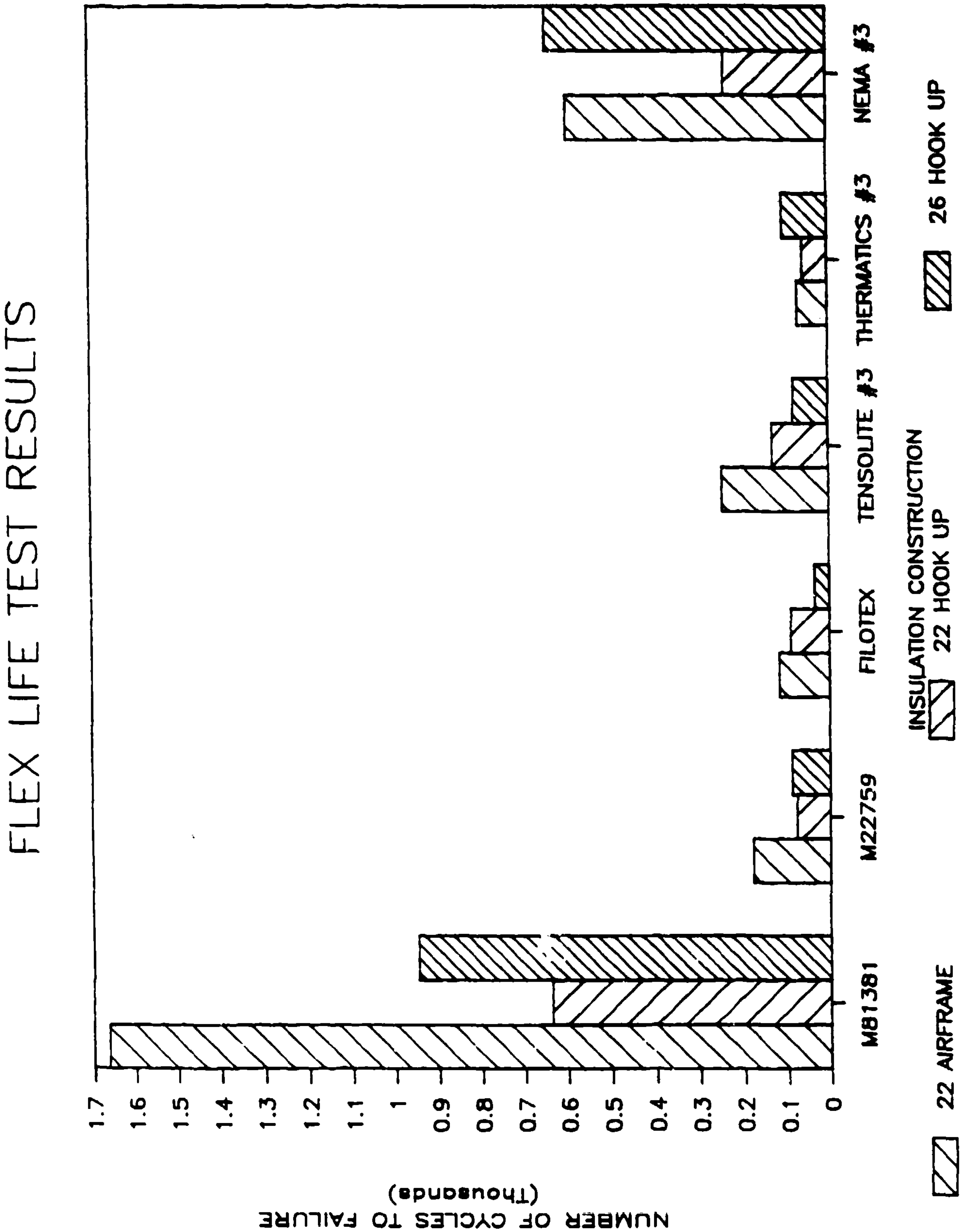


FIGURE 5.70 - FLEX LIFE TEST RESULTS

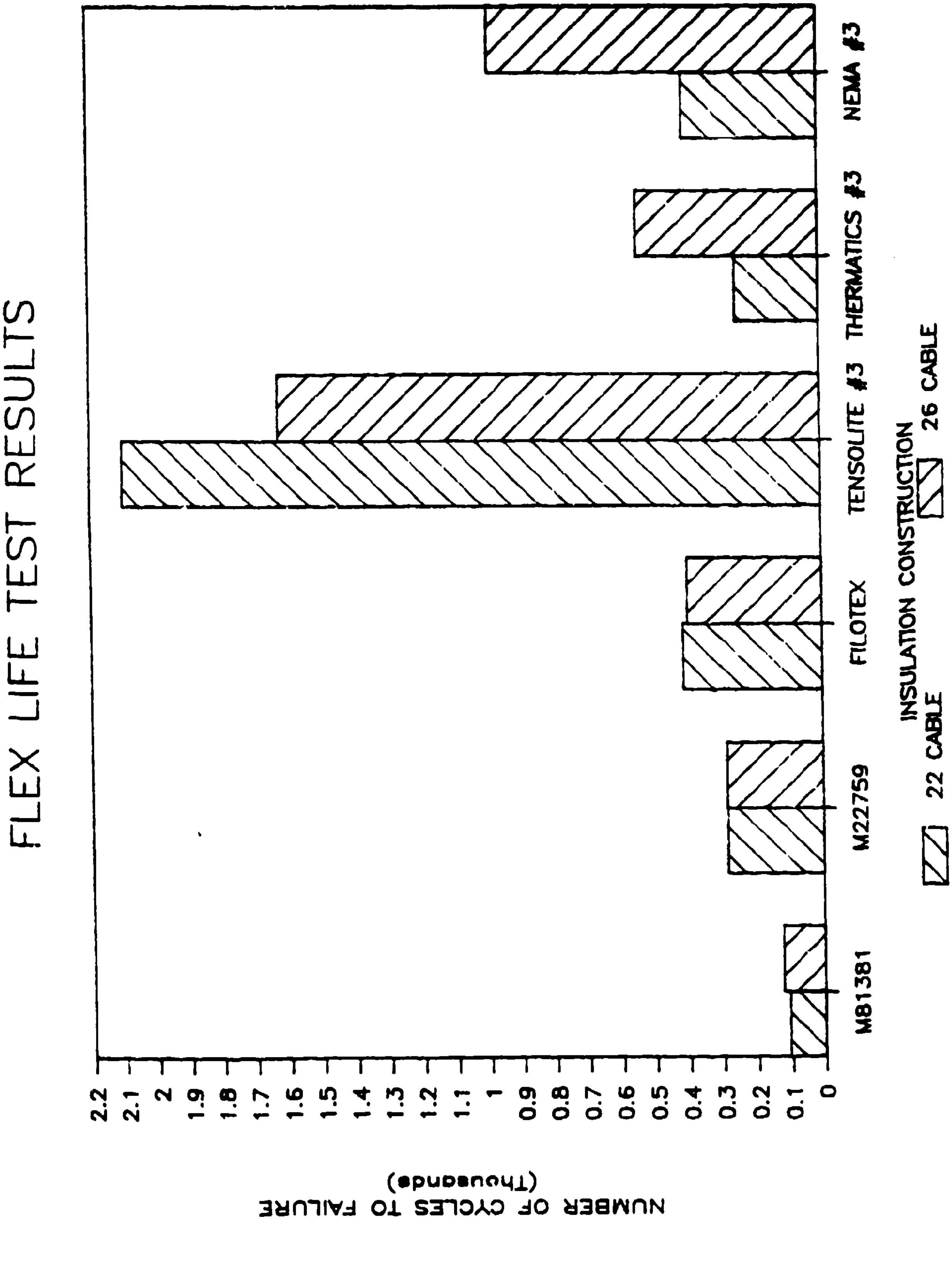


FIGURE 5.71 - FLEX LIFE TEST RESULTS

5.5.6 INSULATION IMPACT RESISTANCE.

5.5.6.1 Scope: This Insulation Impact Resistance Test was used to evaluate insulation integrity after mechanical impact.

5.5.6.2 Reference Procedure: The Insulation Impact Test was conducted according to ASTM D256, Method A, as a guide since SAE AS4373, Method 705 was not available. The test was modified to have a free falling impact head instead of a pendulum type impact head.

5.5.6.3 Specimens: A set of six specimens was fabricated for each impact head incremental weight. Each specimen was cut to a length of three inches with a quarter inch of insulation removed from one end of the specimen.

5.5.6.4 Test Equipment: A one inch long carbon steel drill rod with a diameter of 0.0625±0.0005 inches was used as the impact edge. The impact edge was attached to the holding fixture which was secured to the impact head. This was accomplished by silver soldering the ends of the rod to the holding fixture. The impact head had a threaded rod vertically inserted in it's center to have the capability of affixing additional weights to the head such that the weight was centered about the impact edge. The impact head had two sets of circulating bearings to

reduce friction between the bearings and the two vertical 0.5 inch carbon drill rods. The carbon drill rods were used to assure proper orientation of the impact edge at impact. A 3 x 1 x 0.5 inch steel specimen mounting plate was mounted and centered on the PCB Piezoelectronics 6,000 pound Quartz Force Link (MD 410479). This piezoelectric force transducer was used to measure the peak dynamic force exerted on the specimen. The force transducer was secured to the test base plate using "C" clamps. The force transducer required an Endevco Signal Conditioner Model 2775 (MD 111328) and the force was recorded on a Honeywell 1858 Visicorder (MD 090694). The base plate of the test setup was secured to the bench top using "C" clamps. A small electromagnet was used as the releasing mechanism of the impact head so as to not introduce any extraneous forces.

A 24 volt detection circuit was used to detect continuity between the conductor and the impact head at time of impact. The steel mounting plate was isolated from the detection circuit. The Honeywell 1858 Visicorder recorded the results of the detection circuit.

Photographs of the test setup and equipment are presented in Figures 5.73 through 5.75.

5.5.6.5 Test Procedure: The weight of the impact head and any additional weights were recorded. A calibration test was performed prior to testing any specimens at the specified

head weight and height. The calibration consisted of a set of six impacts upon a 0.0625 inch diameter carbon steel drill rod. The six force values acquired were averaged to obtain an average force of impact for the particular head weight at the specified height.

A specimen was secured to the stainless steel base plate perpendicular to the impact edge by the use of three mil Teflon tape. The specimen laid flat against the stainless steel plate. The recording instrumentation was started and the impact head was electromechanically released. The impact head was released to provide a 3.00±0.0625 inch "free fall" upon the specimen for 22 gauge specimens and 1.00±0.0625 inches for the 26 gauge specimens. Any subsequent impacts on the specimen due to rebounds were permitted. The initial force (maximum force) at impact was recorded and the detector circuit checked for continuity. The force values obtained when impacting a specimen were used to insure consistent impact values. A failure was defined as the force value to obtain electrical continuity between the conductor and the impact head. Six impact tests were conducted for each weight of the impact head.

The insulation impact test was repeated on new specimens with an incremental increase in weight of the impact head until 50% of the tested specimens failed. A calibration test was conducted for each additional increase in impact head weight.

5.5.6.6 Test Results: The force required to fail 50% of the specimens tested is presented in Tables 5.71 through 5.73 with graphical representation of the data presented in Figure 5.72.

TABLE 5.71 - INSULATION IMPACT TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE TO FAIL 50% OF THE SPECIMENS (POUNDS)	MEASURED WEIGHT OF IMPACT HEAD (GRAMS)	DROP HEIGHT (INCHES)
201	M81381	377	595.6	3
206	M22759	293	378.8	3
236	FILOTEX	146	175.7	3
241	TENSOLITE #3	215	270.4	3
246	THERMATICS #3	196	229.4	3
256	NEMA #3	302	388.8	3

TABLE 5.72 - INSULATION IMPACT TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE TO FAIL 50% OF THE SPECIMENS (POUNDS)	MEASURED WEIGHT OF IMPACT HEAD (GRAMS)	DROP HEIGHT (INCHES)
202	M81381	300	425.9	3
207	M22759	157	202.5	3
237	FILOTEX	157	202.5	3
242	TENSOLITE #3	209	274.4	3
247	THERMATICS #3	133	165.7	3
257	NEMA #3	294	373.9	3

TABLE 5.73 - INSULATION IMPACT TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE FORCE TO FAIL 50% OF THE SPECIMENS (POUNDS)	MEASURED WEIGHT OF IMPACT HEAD (GRAMS)	DROP HEIGHT (INCHES)
203	M81381	168	402.4	1
208	M22759	85	196.3	1
238	FILOTEX	90	217.6	1
243	TENSOLITE #3	103	227.6	1
248	THERMATICS #3	90	217.6	1
258	NEMA #3	131	308.5	1

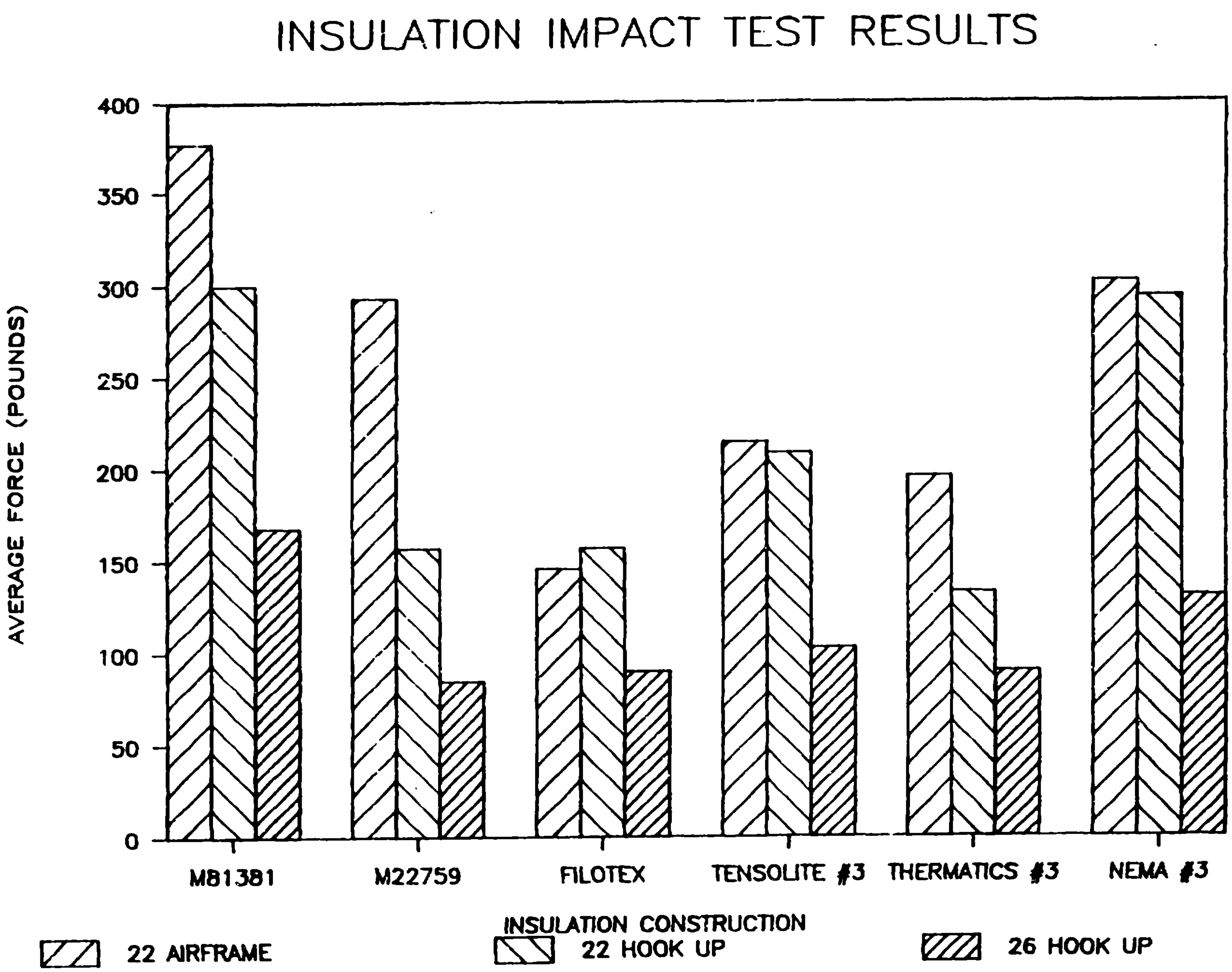


FIGURE 5.72 - INSULATION IMPACT TEST RESULTS

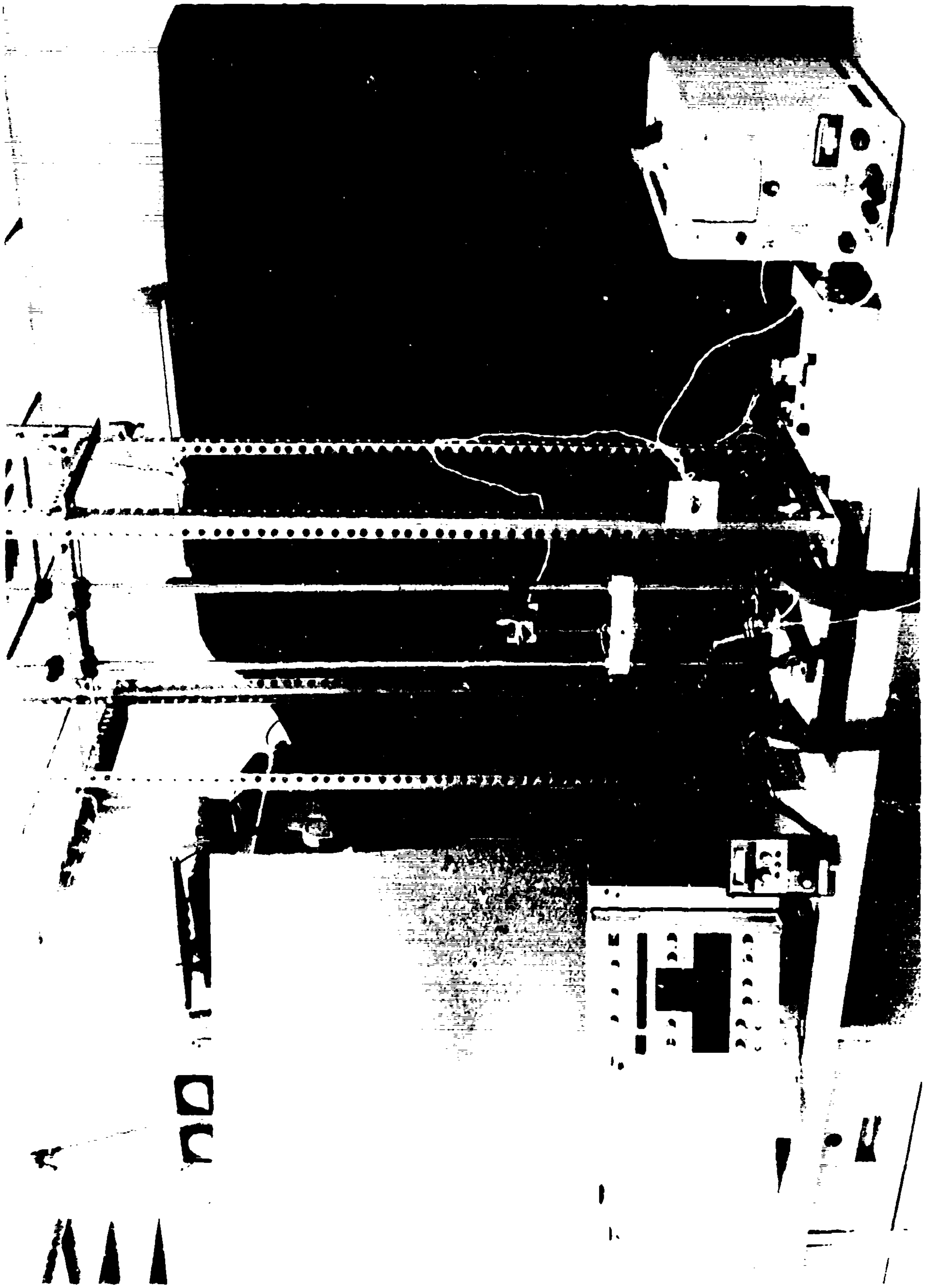


FIGURE 5.[illegible] - INSULATION IMPACT TEST SETUP

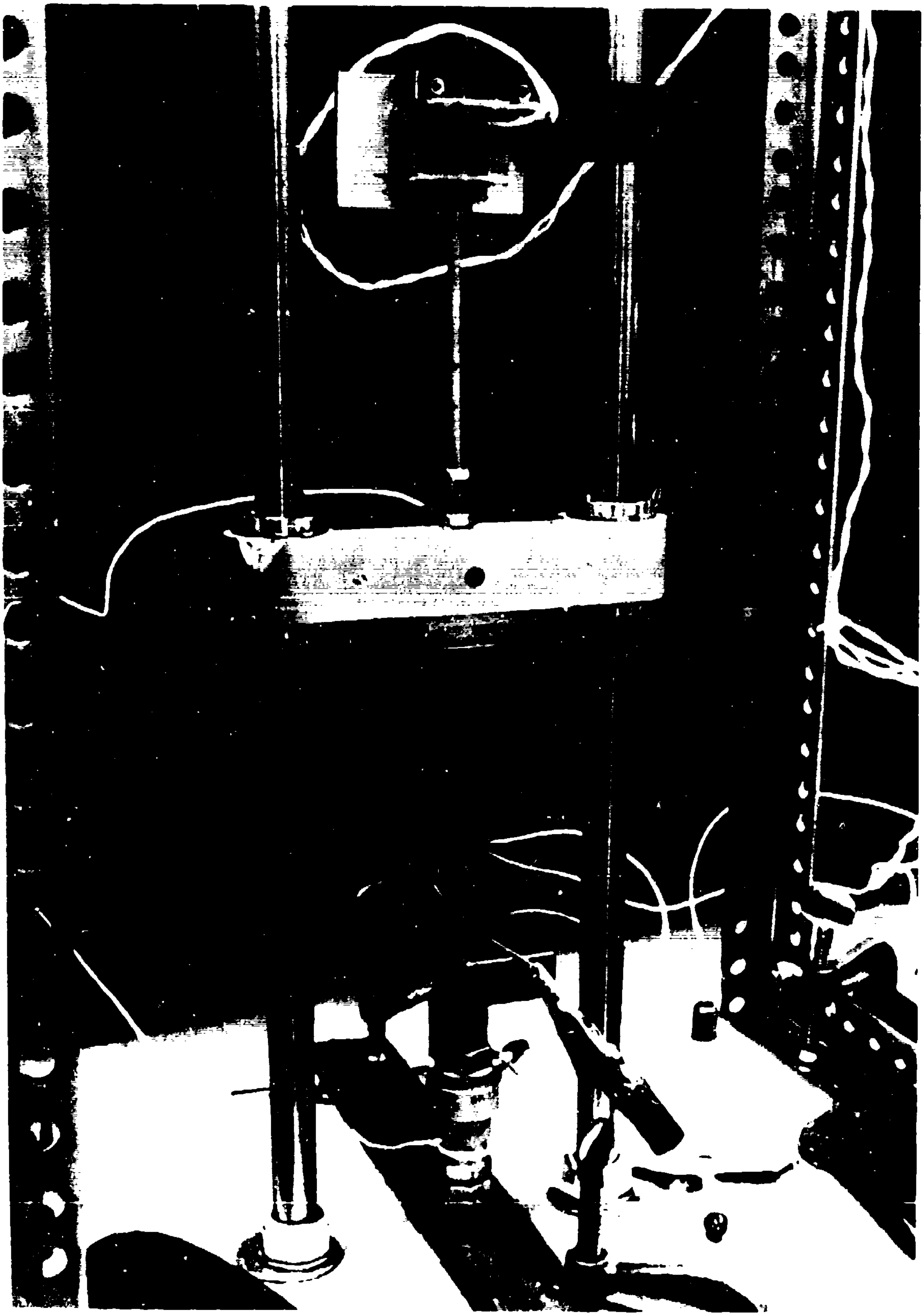


FIGURE 5.74 - INSULATION IMPACT TEST FIXTURE BEFORE RELEASE

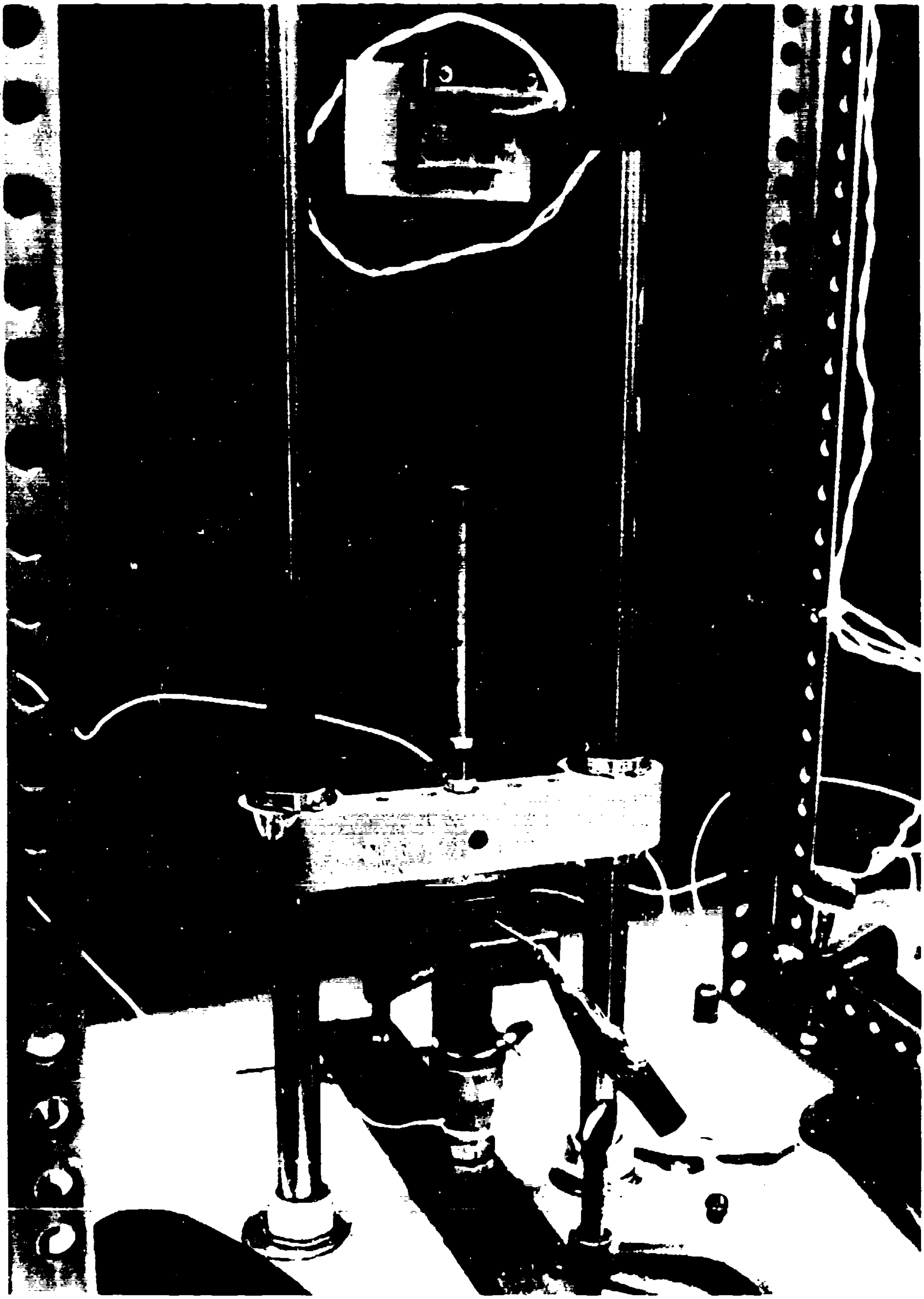


FIGURE 5.75 - INSULATION IMPACT TEST FIXTURE AFTER RELEASE

5.5.7 INSULATION TENSILE STRENGTH AND ELONGATION.

5.5.7.1 Scope: The Insulation Tensile Strength and Elongation Test was used to produce tensile and elongation data for comparison of electrical insulations.

5.5.7.2 Reference Procedure: The Insulation Tensile Strength and Elongation Test was conducted according to Method 706 of SAE AS4373, which is based upon ASTM D3032.17.

5.5.7.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire and 22 gauge, 5.8 mil wall, hook up wire. Six specimens were constructed from each sample for each of two pull rates. A 24 inch specimen had two notches that circularly severed the insulation. The notches were made using an X-acto knife and the insulation flexed until the notch propagated around the entire circumference of the wire. The notches were placed four inches apart at the 10 and 14 inch marks on the the 24 inch specimen. Each end of the specimen was then wrapped around a 1.25 inch diameter mandrel and secured to the mandrel by hose clamps. A tensile force was slowly applied to the wire to elongate the conductor and enable the four inch severed segment of insulation to slide freely on the conductor. The conductor was cut and the insulation specimen was removed from the conductor.

5.5.7.4 Test Equipment: A 200 pound Instron Load Frame (MD 060343-2) was used to conduct the insulation tensile pull test. A load cell was included in the test configuration to monitor the amount of force exerted on the specimen during the test. The load cell output was connected to a strip chart recorder for data reduction. The jaws of the setup were pneumatically operated and had a 0.5 inch piece of aluminum oxide placed on each side of the specimen and one inch hard rubber padded jaws to prevent slippage of the specimen. The 0.5 inch piece of aluminum oxide was secured to the portion of the hard rubber pad that was farthest from the test portion of the specimen. The hard rubber pads were rounded at the edges to minimize the effects of a stress point where contacting the specimen.

Photographs of the test setup and equipment are presented in Figures 5.80 through 5.81.

5.5.7.5 Test Procedure: One inch of the specimen was inserted between the pneumatically operated, hard rubber padded jaws. A layer of aluminum oxide was placed between the specimen and the hard rubber pads. The jaws were initially separated by a distance of 2 inches. After the specimen was placed between the clamps, the jaws were closed. The strip chart recorder was started and the Instron Load Frame was operated at a separation rate of two inches per minute. The specimen was pulled

until total separation occurred. The maximum force to rupture and the elongation of the initially exposed two inches of the specimen was determined from the strip chart measurements.

The test was conducted as stated previously on a second set of six specimens except at a pull rate of 20 inches per minute.

The tensile strength of the insulation and the percentage of elongation were calculated from the maximum force to rupture and elongation data acquired from the strip charts. Tensile strength was defined as the force value observed at rupture divided by the cross sectional area of the insulation. The cross sectional area of the insulation was determined by using the data acquired from the Finished Wire Diameter Test. The cross sectional area was determined by calculating the area of the specimen from the Finished Wire Diameter Test measurements and then subtracting the area of the conductor from the Conductor Diameter Test measurements. The percentage elongation was determined by comparing the percentage difference from the initially exposed two inch specimen to the length of the specimen at rupture. The measurements acquired and calculated were recorded in the test results.

5.5.7.6 **Test Results:** The average tensile strength and the average percentage elongation of the samples tested is presented in Tables 5.74 through 5.75 with graphical representation of the data presented in Figures 5.76 through 5.79.

TABLE 5.74 - INSULATION TENSILE STRENGTH AND ELONGATION TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

		PULL RATE: 2 IN./MIN.		PULL RATE: 20 IN./MIN.	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE TENSILE STRENGTH (POUNDS PER SQUARE IN.)	AVERAGE PERCENT ELONG.	AVERAGE TENSILE STRENGTH (POUNDS PER SQUARE IN.)	AVERAGE PERCENT ELONG.
101	M81381	21,255	66	23,313	108
106	M22759	6,581	139	7,170	140
236	FILOTEX	12,118	73	12,719	83
141	TENSOLITE #3	9,822	140	10,233	132
146	THERMATICS #3	17,801	108	19,382	108
156	NEMA #3	13,102	107	13,748	107

TABLE 5.75 - INSULATION TENSILE STRENGTH AND ELONGATION TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

		PULL RATE: 2 IN./MIN.		PULL RATE: 20 IN./MIN.	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE TENSILE STRENGTH (POUNDS PER SQUARE IN.)	AVERAGE PERCENT ELONG.	AVERAGE TENSILE STRENGTH (POUNDS PER SQUARE IN.)	AVERAGE PERCENT ELONG.
102	M81381	22,663	84	24,693	109
107	M22759	6,406	153	6,479	137
237	FILOTEX	13,640	110	14,677	123
142	TENSOLITE #3	11,147	160	11,255	160
147	THERMATICS #3	14,316	111	14,529	104
157	NEMA #3	10,963	71	12,742	86

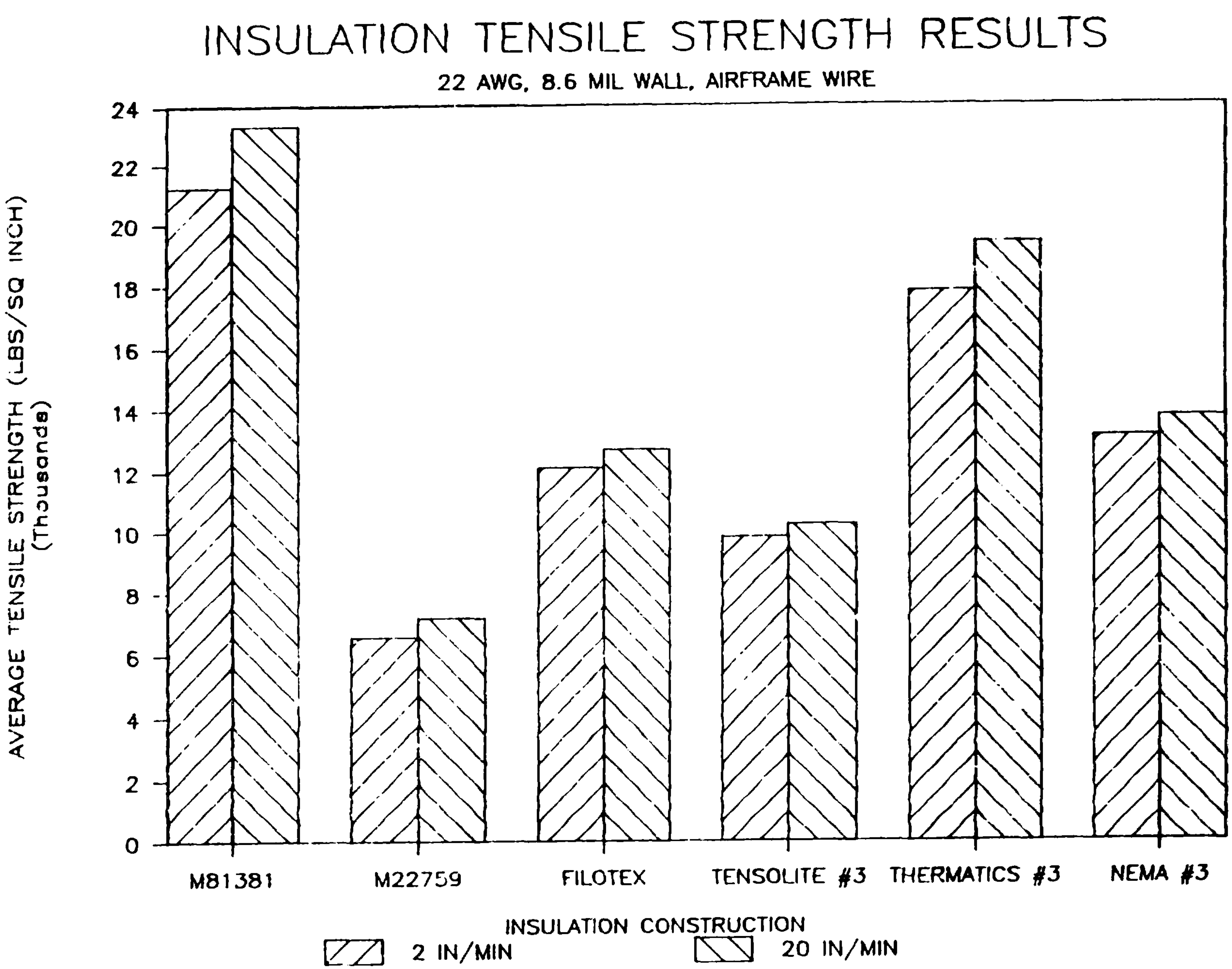


FIGURE 5.76 - INSULATION TENSILE STRENGTH RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

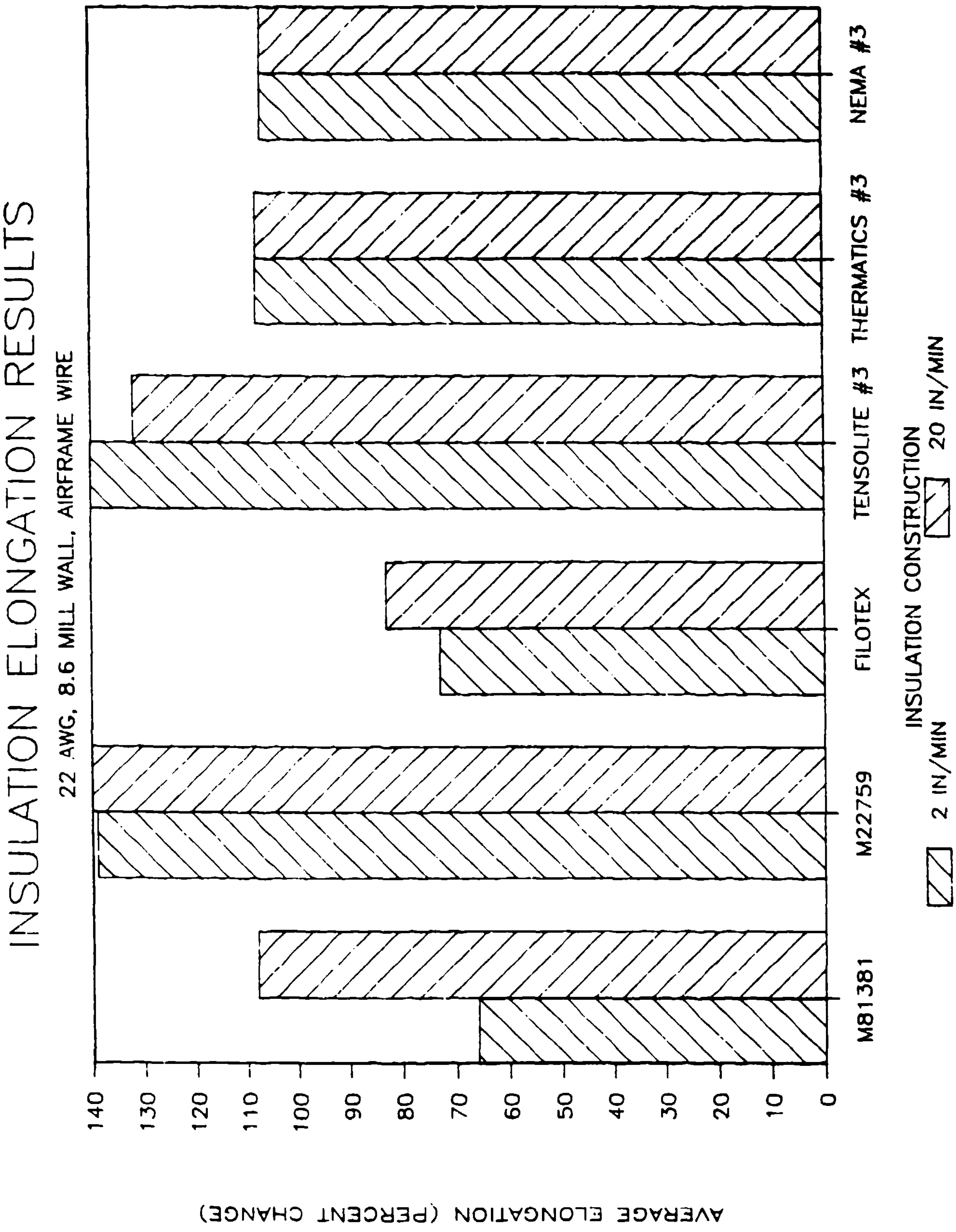


FIGURE 5.77 - INSULATION ELONGATION RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

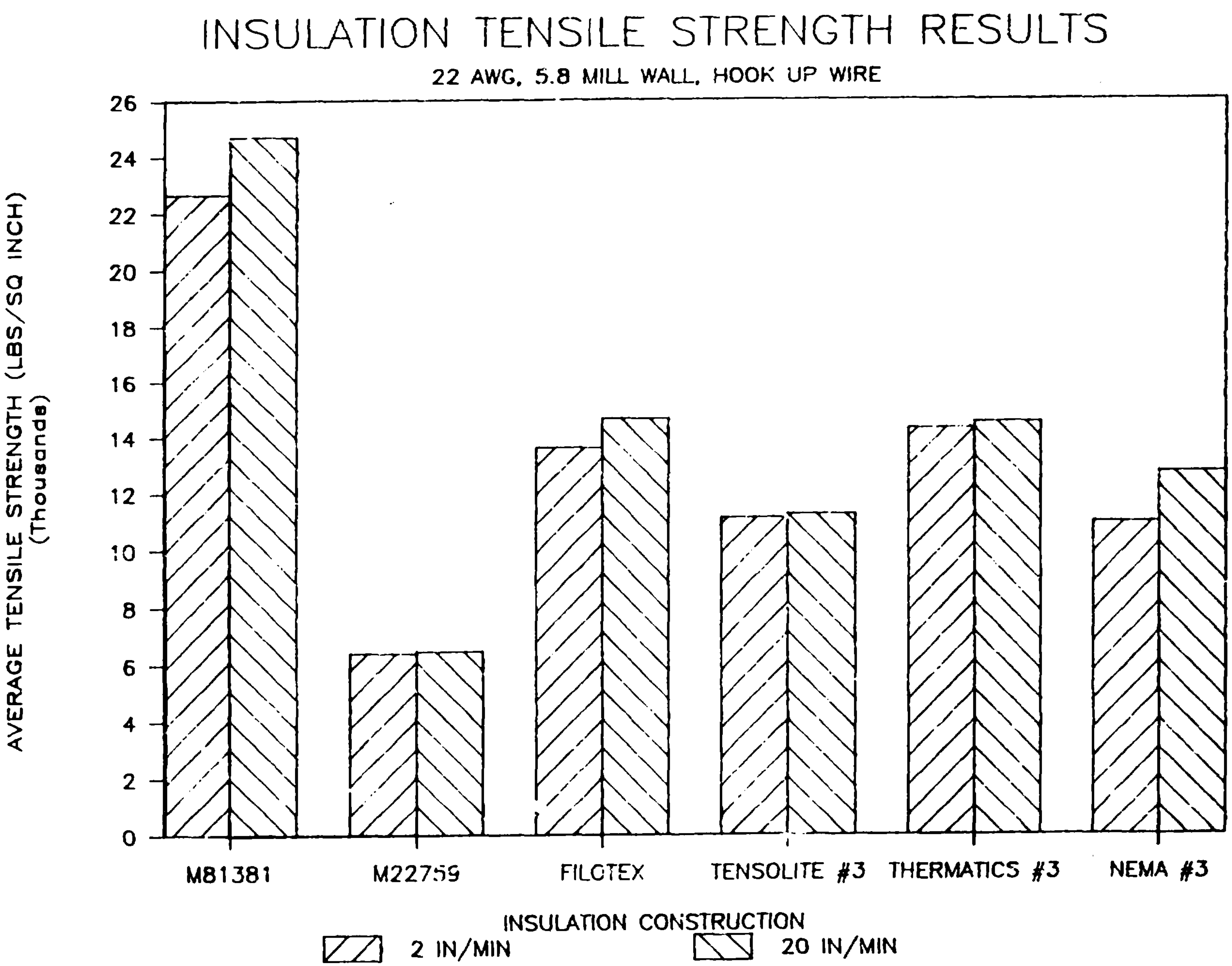


FIGURE 5.78 - INSULATION TENSILE STRENGTH RESULTS,
22AWG, 5.8 MIL WALL, HOOK UP WIRE

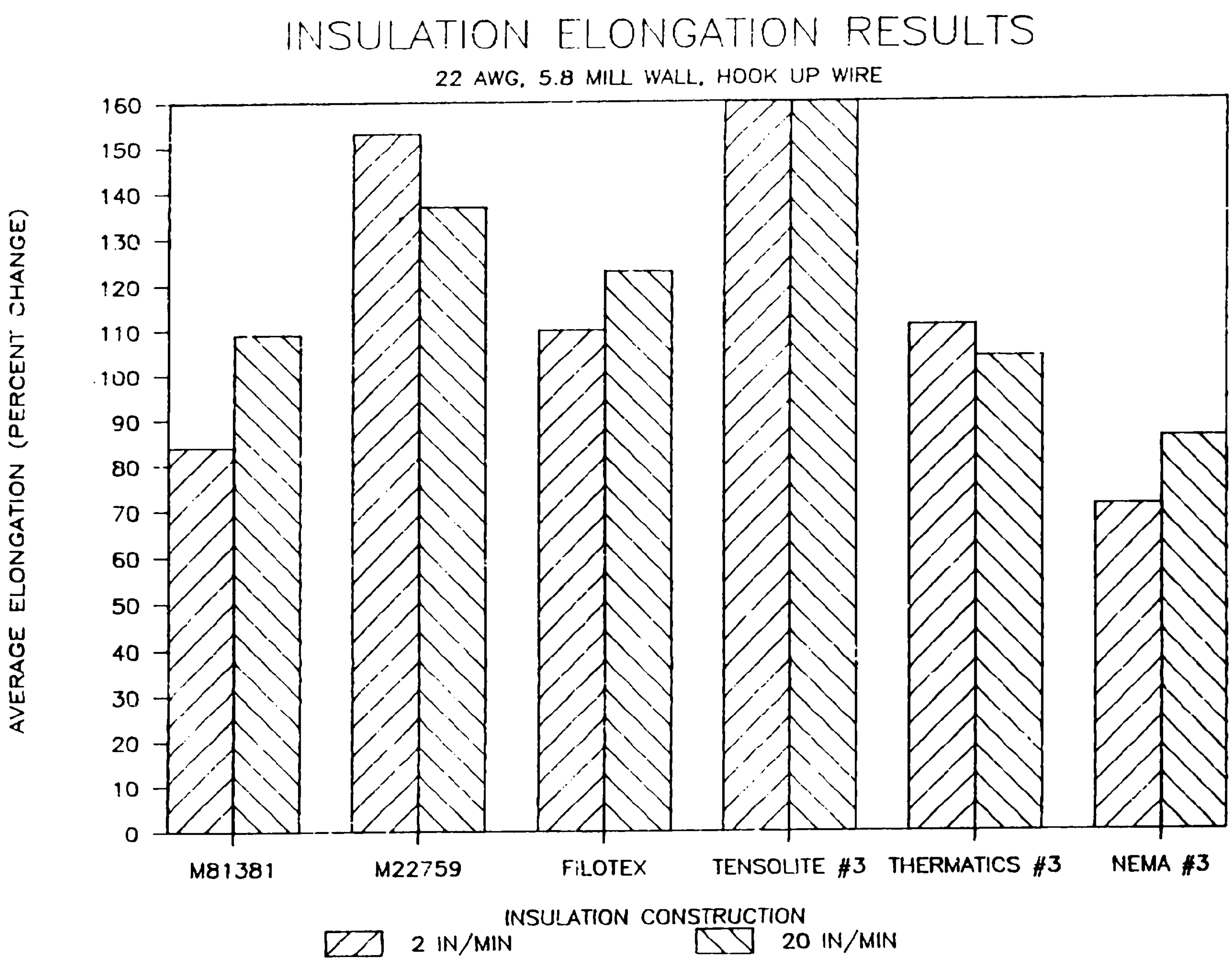


FIGURE 5.79 - INSULATION ELONGATION RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

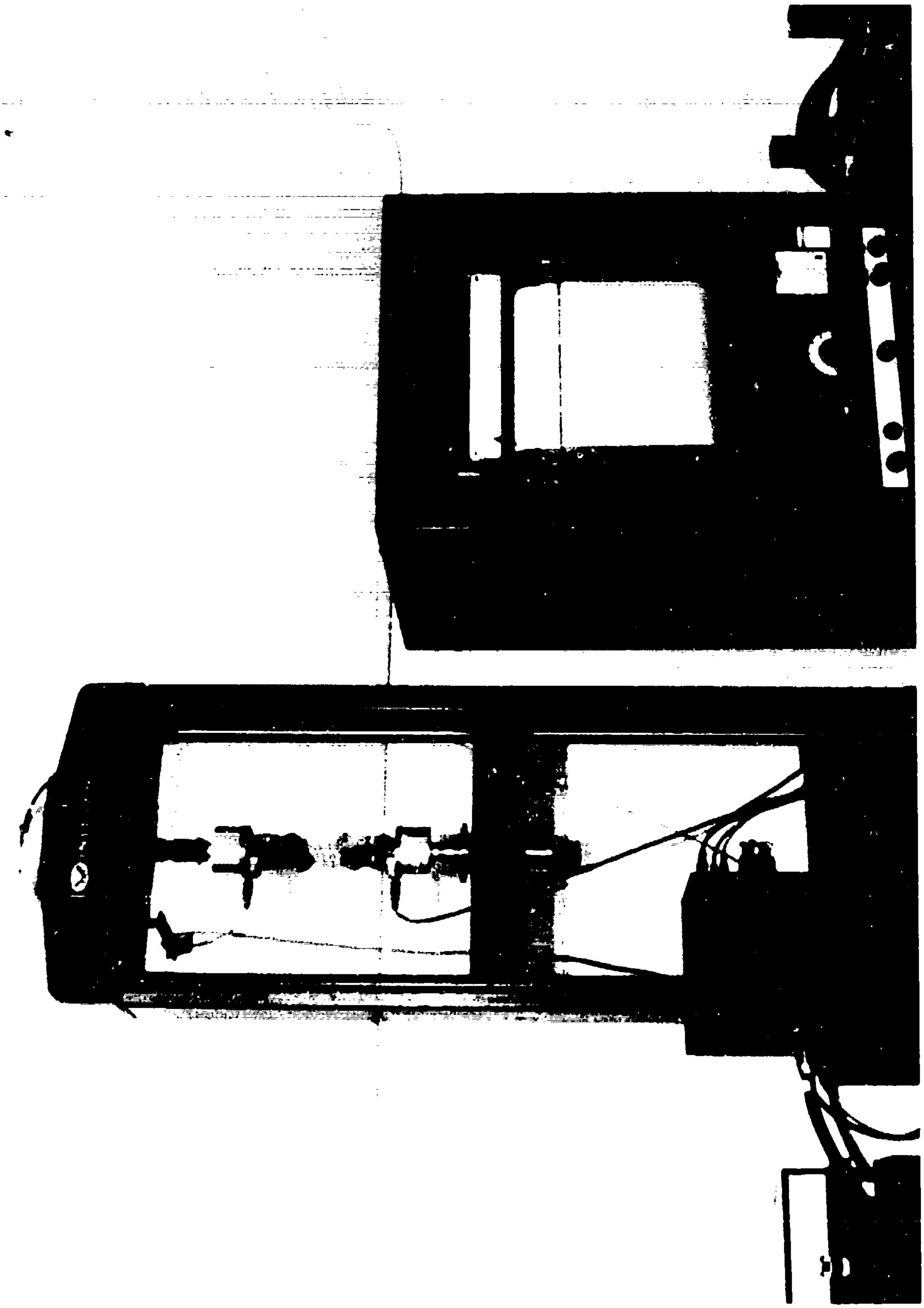


FIGURE 5.80 - INSULATION TENSILE STRENGTH AND ELONGATION TEST SETUP

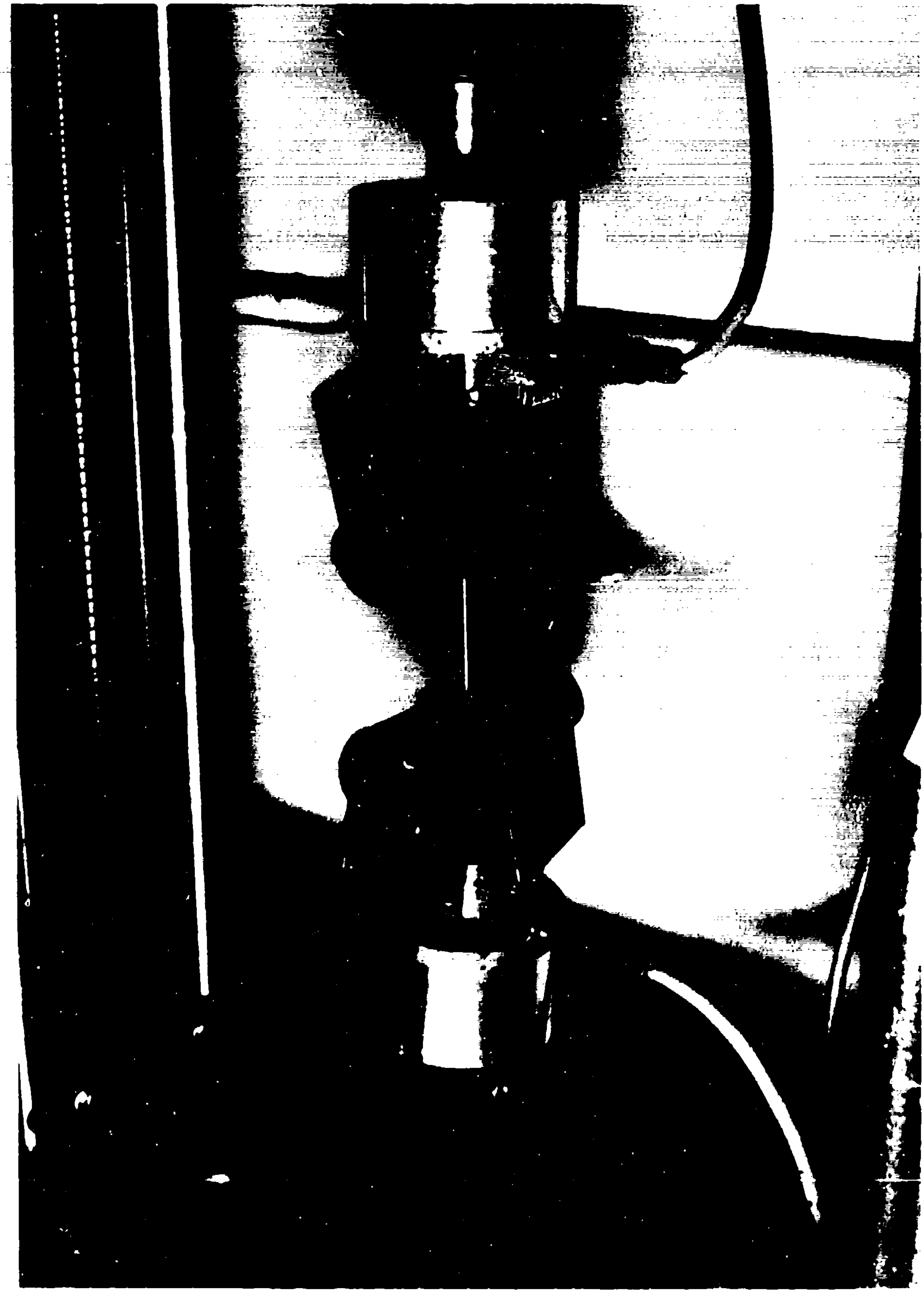


FIGURE 5.81 - INSULATION TENSILE STRENGTH AND ELONGATION TEST SPECIMEN CONFIGURATION

5.5.8 NOTCH PROPAGATION.

5.5.8.1 Scope: The Notch Propagation Test was used to evaluate the ability of a wire insulation to withstand notching or nicking without propagating the damage down to the conductor.

5.5.8.2 Reference Procedure: The Notch Propagation Test was performed according to the procedure described in Method 707 of SAE AS4373 with the addition of a Voltage Withstand Test to confirm a failure. This test assumed that all hook up wire had a wall thickness of 0.0058 inches and all airframe wire had a wall thickness of 0.0086 inches even though there were known differences. The test utilized tools with notch depths of 50% and 66.67% of the assumed wall thickness.

5.5.8.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. Six specimens were constructed for each notch depth for a total of 12 specimens. The specimens were cut into lengths of six inches with a quarter inch of insulation removed from both ends and #10 ring terminals crimped on both conductor ends.

5.5.8.4 Test Equipment: This test utilized the notching tool described in SAE AS4373, Figure 1 of Method 707. The notch depths used were 5.7 mils (67% of 8.6 mils) and 4.3 mils (50% of 8.6 mils) for the 8.6 mil wall specimens and 3.9 mils (67% of 5.8 mils) and 2.9 mils (50% of 5.8 mils) for the 5.8 mil wall specimens. The notch depths were set and measured using a Nikon microscope (MD 115812) with a calibrated position sensor.

Mandrels approximately six times the diameter of the wire were manufactured for use in the wrapping segment of the test. The diameters used were 0.28125 inches for 22 gauge, 8.6 mil wall, airframe wire; 0.25 inches for 22 gauge, 5.8 mil wall, hook up wire; and 0.1875 for 26 gauge, 5.8 mil wall, hook up wire.

A Slaughter Dielectric Tester (MD 78995) was used to conduct the Voltage Withstand Test. The voltage was monitored by a Fluke 8050A Digital Multimeter (MD 011821) through a Fluke 80K-6 High Voltage Probe (MD 189698).

Photographs of the test setup and equipment are provided in Figures 3.33 through 3.34.

5.5.8.5 Test Procedure: The test was conducted by first securing the specimen to a steel plate to hold the wire secure during notching. The notching tool was placed upon the central portion of the wire and a black felt tip pen was used to mark the location of the tool on the specimen. The mark was necessary to identify the

location of the notch and to assist the operator in keeping the notch on the outside of the mandrel during wrapping. A 1.1 pound weight was placed on top of the tool, and the tool was pulled across the wire one time for a length of one inch of the blade and removed from the plate.

The wire was fastened to the appropriate mandrel on one end while the other had a one pound weight attached to apply tension during wrapping. With the notch constantly facing away from the mandrel, the wire was wound and unwound around the mandrel for one revolution prior to the notch (lengthwise) and one revolution following the notch (lengthwise) for 100 cycles (one cycle = one forward wind + one reverse wind) or until the conductor became visible. The specimen was wrapped around the mandrel at an approximate rate of 30 revolutions per minute. The specimen was removed from the mandrel and the number of cycles to failure was recorded.

The specimen was immersed in a 1% salt solution for a one minute soak time and subjected to a 2500 volt, 60 Hertz, Voltage Withstand Test. The voltage was applied at a rate of 500 volts per second and remained at 2500 volts for 10 seconds. A failure was defined as arcing at the notch or a leakage current greater than one milliamp.

The test was first conducted at the 66.67% notch depth. If any of the six specimens failed, the test was repeated with a notch depth at 50%. The results recorded the number of cycles to failure with a 100 cycle maximum and the results of the Voltage Withstand Test.

5.5.8.6 Test Results: The average number of cycles to failure and the results of the Voltage Withstand Test are presented in Tables 5.76 through 5.78. None of the specimens failed the 66.67% notch depth so the 50% notch depth was not tested.

TABLE 5.76 - NOTCH PROPAGATION TEST RESULTS ON UNCONDITIONED, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

		NOTCH DEPTH = 5.7 MIL	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	RESULTS OF WET DIELECTRIC (PASS/FAIL)
101	M81381	>100.0	6 / 0
106	M22759	>100.0	6 / 0
136	FILOTEX	>100.0	6 / 0
141	TENSOLITE #3	>100.0	6 / 0
146	THERMATICS #3	>100.0	6 / 0
156	NEMA #3	>100.0	6 / 0

TABLE 5.77 - NOTCH PROPAGATION TEST RESULTS ON UNCONDITIONED, 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

		NOTCH DEPTH = 3.9 MIL	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	RESULTS OF WET DIELECTRIC (PASS/FAIL)
102	M81381	>100.0	6 / 0
107	M22759	>100.0	6 / 0
137	FILOTEX	>100.0	6 / 0
142	TENSOLITE #3	>100.0	6 / 0
147	THERMATICS #3	>100.0	6 / 0
157	NEMA #3	>100.0	6 / 0

TABLE 5.78 - NOTCH PROPAGATION TEST RESULTS ON UNCONDITIONED, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

		NOTCH DEPTH = 3.9 MIL	
SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE NUMBER OF CYCLES TO FAILURE	RESULTS OF WET DIELECTRIC (PASS/FAIL)
103	M81381	>100.0	6 / 0
108	M22759	>100.0	6 / 0
138	FILOTEX	>100.0	6 / 0
143	TENSOLITE #3	>100.0	6 / 0
148	THERMATICS #3	>100.0	6 / 0
158	NEMA #3	>100.0	6 / 0

5.5.9 WIRE TO WIRE RUB TEST.

5.5.9.1 Scope: The Wire to Wire Rub Test compares abrasion resistance of various wire insulations that are rubbed against each other.

5.5.9.2 Reference Procedure: The Wire to Wire Rub Test was conducted at Douglas Aircraft Company (DAC) according to a procedure developed at DAC. A copy of the test procedure was submitted to the Department of Air Force in the 13 September 1990 CDRL monthly report.

5.5.9.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire. Four specimens were cut to a length of 15 inches for each wire sample. Two of the test specimens were tested with each control specimen of 22 gauge, 8.6 mil wall, M81381 airframe wire and 22 gauge, 8.6 mil wall, M22759 airframe wire. The M81381 and M22759 wires were cut to a length of 20 inches.

5.5.9.4 Test Equipment: An Eberbach Model #6000 wire to wire abrasion fixture was used to conduct the test. The machine was designed to abrade twelve wires simultaneously at a rate of 48 cycles per minute. The setup included a counter to record the number of cycles. The specimens under test were affixed to a metal plate that was in motion during the test. One end of each

control specimen, either M81381 or M22759, was secured to a stationary plate in the test fixture. The other end of the control specimen was placed over a pulley and had a one pound weight attached.

Photographs of the test setup and equipment are presented in Figures 5.84 through 5.85.

5.5.9.5 Test Procedure: The first set of twelve test specimens was placed in the test fixture and affixed to the movable plate. One end of each control specimen of M81381 and M22759 was secured to the stationary plate of the test fixture. One 360° twist was between each test specimen and it's control specimen. The control specimen was placed over a pulley and had a one pound weight attached to apply tension during the wire to wire abrasion. After the first set of twelve specimens was placed in the test setup, the Wire to Wire Rub Test was initiated at a rate of 48 cycles per minute. The test was monitored each working day to inspect the specimens for failures and the data was recorded. A failure was defined as any visible sign of conductor on the specimen under test. Photos were acquired of each test specimen at 250 hours, 500 hours, and 870 hours from the initiation of the test. A maximum of 2,500,000 cycles (870 hours) were conducted on the test specimens. At the completion of the test, a relative description of the wear on the specimens was conducted and recorded.

5.5.9.6 **Test Results:** The average number of cycles to failure was calculated using 2,500,000 cycles for the specimens that passed the test. The average number of cycles to failure and a description of the wear on the wire insulation at the completion of the 2,500,000 cycles is presented in Tables 5.79 through 5.80 with graphical representation of the data presented in Figures 5.82 through 5.83.

TABLE 5.79 - WIRE TO WIRE RUB TEST RESULTS WITH M81381 IN MOTION ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVG. NUMBER OF CYCLES TO EXPOSE CONDUCTOR (MAX. OF 2,500,000)	INSULATION DESCRIPTION OF WEAR ON SPECIMENS
101	M81381	2,500,000	MODERATE
106	M22759	1,968,560	1 FAILURE
136	FILOTEX	2,500,000	MODERATE
141	TENSOLITE #3	2,500,000	MODERATE
146	THERMATICS #3	2,500,000	MODERATE
156	NEMA #3	1,715,376	2 FAILURES

TABLE 5.80 - WIRE TO WIRE RUB TEST RESULTS WITH M22759 IN MOTION ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVG. NUMBER OF CYCLES TO EXPOSE CONDUCTOR (MAX. OF 2,500,000)	INSULATION DESCRIPTION OF WEAR ON SPECIMENS
101	M81381	2,500,000	NEGLIGIBLE
106	M22759	2,500,000	NEGLIGIBLE
136	FILOTEX	2,500,000	MODERATE
141	TENSOLITE #3	2,500,000	MODERATE
146	THERMATICS #3	2,500,000	NEGLIGIBLE
156	NEMA #3	2,500,000	MODERATE

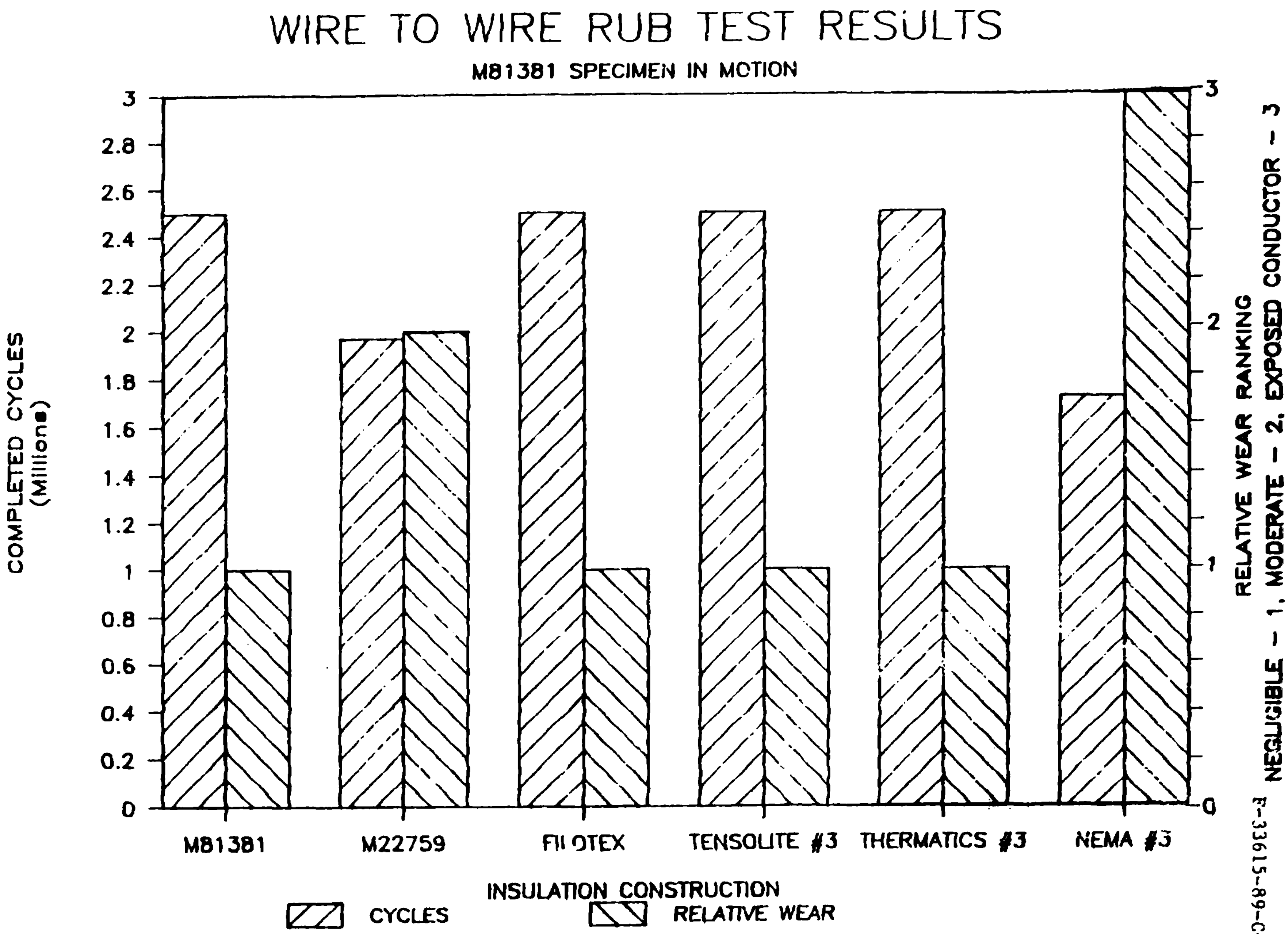


FIGURE 5.82 - WIRE TO WIRE RUB TEST RESULTS, M81381 SPECIMEN IN MOTION

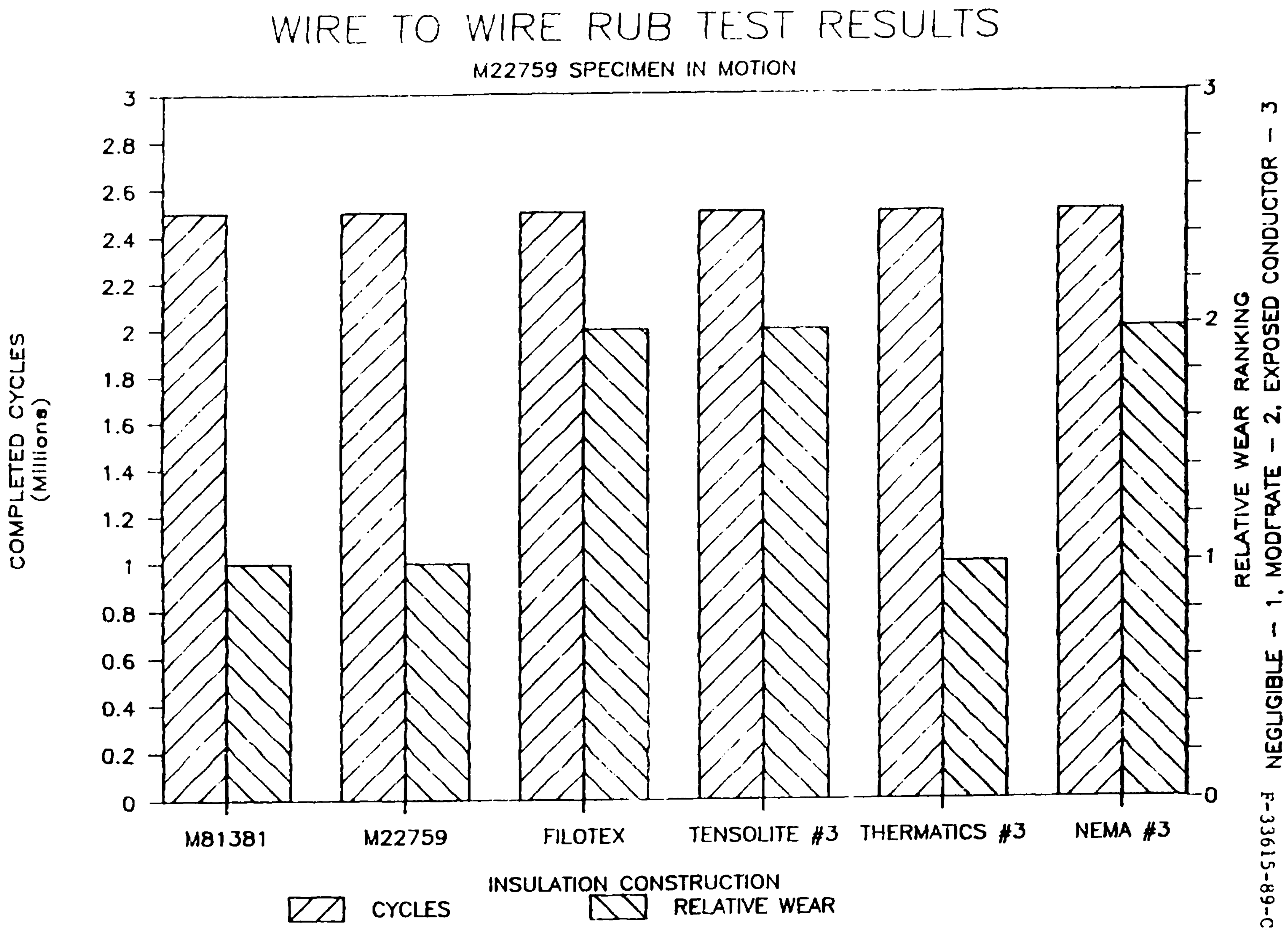


FIGURE 5.83 - WIRE TO WIRE RUB TEST RESULTS, M22759 SPECIMEN IN MOTION

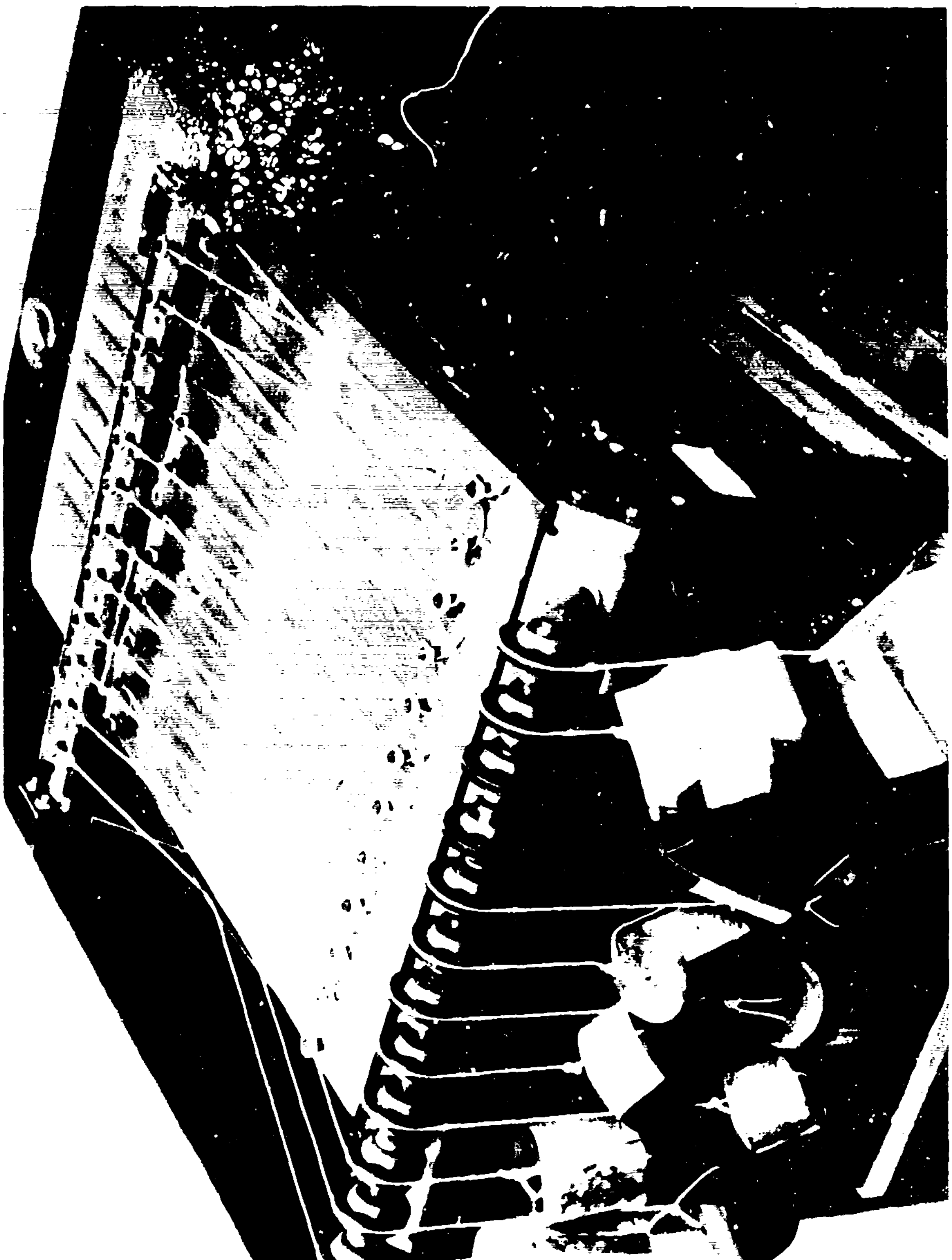


FIGURE 5.84 - WIRE TO WIRE RUB TEST SETUP

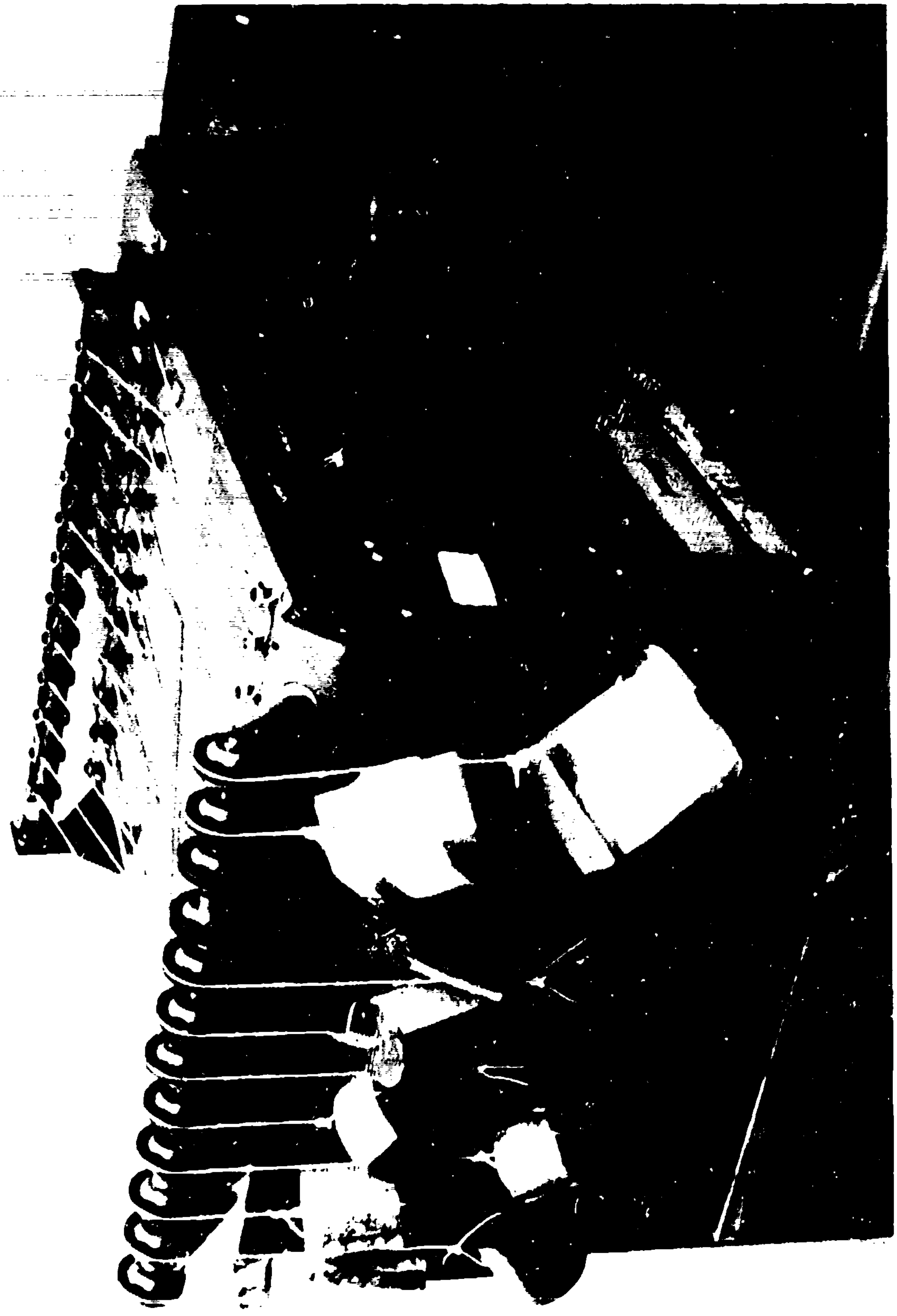


FIGURE 5.85 - WIRE TO WIRE RUB TEST SETUP

5.6 THERMAL TESTS

5.6.1 AGING STABILITY.

5.6.1.1 Scope: The Aging Stability Test was used to determine the mechanical properties of the cable jacket after exposure for 96 hours at 230°C (446°F).

5.6.1.2 Reference Procedure: The Aging Stability Test was conducted according to paragraph 4.5.10 of MIL-C-27500G since no SAE procedure existed. A Voltage Withstand Test, Method 510 of SAE AS4373, was added to detect cracks that would not be detected in the visual inspection of the jacket.

5.6.1.3 Specimens: Specimens were constructed from 22 gauge and 26 gauge, two conductor, twisted, shielded and jacketed cable samples. Six unconditioned specimens of each sample were cut to a length of 25 inches. A 1.5 inch segment of the jacket was removed from each end of the specimen. A dental pick was used to pull the primary wires out between the braid of the shield, 1.5 inches from the end of the specimen. The shield was rolled together and a #10 ring terminal was crimped on the shield. The wires had a quarter inch of insulation removed and the conductors were twisted together. A #10 ring terminal was crimped on the twisted pair of

conductors. The same configuration was assembled at the opposite end of the specimen.

The specimens were mounted in a holding fixture that suspended the specimens in free air by placing fiberglass lacing tape (MIL-43435B, type IV) through the ring terminals at each end of the specimen and securing the lacing tape to the holding fixture.

5.6.1.4 Test Equipment: A Blue M Environmental Chamber (MD 66618) was used for the elevated temperature of 230°C (446°F). The chamber's temperatures were monitored using a Fluke Datalogger (MD 084509) with type T thermocouples.

Mandrels were constructed for the wrapping segment of the test. The mandrel diameters used were 1.0 inch for the 22 gauge specimens and 0.75 for the 26 gauge specimens.

A Slaughter Dielectric Tester (MD 78995) was used to conduct the Voltage Withstand Test. The voltage was monitored by a Fluke 8050A Digital Multimeter (MD 011821) through a Fluke 80K-6 High Voltage Probe (MD 189698).

Photographs of the test setup and the Bend Test fixture are presented in Figures 5.88 through 5.90.

5.6.1.5 Test Procedure: The specimens were secured to a holding fixture so as to suspend the specimens in free air. The chamber was preheated to 230°C (446°F) and the rack of specimens was placed in the chamber. The 96

hours exposure commenced when the chamber recovered to within ±2°C of the rated test temperature. At the conclusion of the thermal aging, the holding fixture and specimens were removed from the chamber and allowed to cool to room temperature for a minimum of 30 minutes prior to initiating the wrapping sequence.

The specimens underwent a Bend Test in which the specimens were wrapped around a mandrel helically for six complete revolutions. The specimen was attached to the mandrel at one end by securing the ring terminal crimped on the shield to the mandrel. The opposite end of the shield had a 1.0 pound weight attached to the 22 gauge specimens and a 0.5 pound weight attached to the 26 gauge specimens. The specimens were wrapped at a rate of 15±3 revolutions per minute for six close turns. At completion of the wrapping sequence, the weights were carefully removed from the specimens so no damage occurred as a result of the recoil of the specimen. The specimens were removed from the mandrels without straightening. The jacket was inspected for cracking, tape edge lift, or other anomalies. The results of the jacket investigation were recorded.

To conclude the test, the specimens underwent a Voltage Withstand Test using Method 510 of SAE AS4373 as a guide. The specimens were submerged as a helical coil to within three inches of the ends in a 1% salt (NaCl) solution. After completion of the four hour soak time, a

potential of 1500 volts at 60 Hertz was applied to the specimen. The test potential maximum was achieved at a ramp rate of 500 volts per second. The potential was applied between the the shield and an electrode placed in the solution to test the jacket integrity. The potential was applied for one minute. The largest leakage current value was recorded, unless a dielectric failure occurred, then the time to failure was recorded and the failure identified. A failure was defined as a specimen having a leakage current greater than five milliamps or a dielectric breakdown.

At the completion of the jacket Voltage Withstand Test, another Voltage Withstand Test was conducted to test the primary wire insulation. A potential of 1500 volts was applied between the commoned conductors and the shield as previously described. The shield was connected to the electrode in the solution by use of a jumper wire. The maximum potential was applied to the specimen for a period of one minute. The largest leakage current value was recorded, unless a dielectric failure occurred, then the time to failure was recorded. A failure was defined as a specimen having a leakage current greater than five milliamps or dielectric breakdown. The results of the dielectric tests were recorded.

The specimens were rinsed in tap water and air dried before placing in storage.

5.6.1.6 Test Results: The tape edge lift observed on the NEMA #3 cable jacket specimens were slight. The edges of the outer tape wrap showed signs of delamination. A color change failure was identified as a change in the original color of the cable jacket as a result of the thermal aging.

The results of the cable jacket inspection and the Voltage Withstand Tests are presented in Tables 5.81 through 5.82 with graphical representation of the data presented in Figures 5.86 through 5.87.

TABLE 5.81 - AGING STABILITY TEST RESULTS ON
22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	CABLE JACKET INSPECTION COLOR CHANGE (P / F)	OBSERVE CRACKS (P / F)	TAPE EDGE LIFT (P / F)	JACKET AVERAGE LEAKAGE CURRENT (MICRO-AMP)	WIRE AVERAGE LEAKAGE CURRENT (MICRO-AMP)
104	M81381	0 / 6	6 / 0	6 / 0	348	230
109	M22759	0 / 6	6 / 0	6 / 0	255	223
239	FILOTEX	6 / 0	6 / 0	6 / 0	177	197
144	TENSOLITE #3	6 / 0	6 / 0	6 / 0	228	170
249	THERMATICS #3	0 / 6	6 / 0	6 / 0	237	250
159	NEMA #3	0 / 6	6 / 0	0 / 6	200	170

TABLE 5.82 - AGING STABILITY TEST RESULTS ON
26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	CABLE JACKET INSPECTION COLOR CHANGE (P / F)	OBSERVE CRACKS (P / F)	TAPE EDGE LIFT (P / F)	JACKET AVERAGE LEAKAGE CURRENT (MICRO-AMP)	WIRE AVERAGE LEAKAGE CURRENT (MICRO-AMP)
105	M81381	0 / 6	6 / 0	6 / 0	252	190
110	M22759	6 / 0	6 / 0	6 / 0	187	170
240	FILOTEX	6 / 0	6 / 0	6 / 0	183	157
145	TENSOLITE #3	6 / 0	6 / 0	6 / 0	200	120
250	THERMATICS #3	0 / 6	6 / 0	6 / 0	220	158
160	NEMA #3	0 / 6	6 / 0	0 / 6	233	230

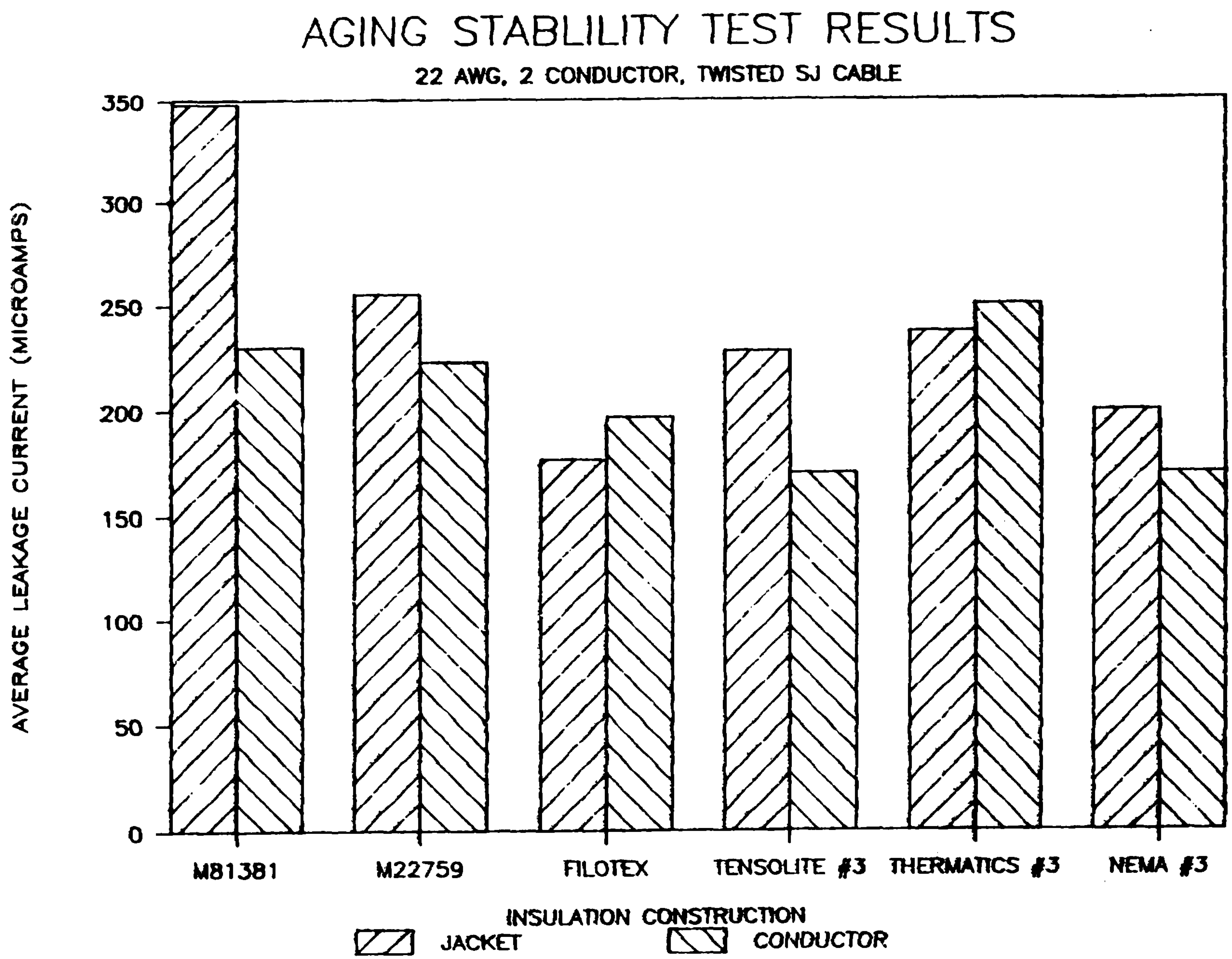


FIGURE 5.86 - AGING STABILITY TEST RESULTS, 22AWG, 2 CONDUCTOR, TWISTED SJ CABLE

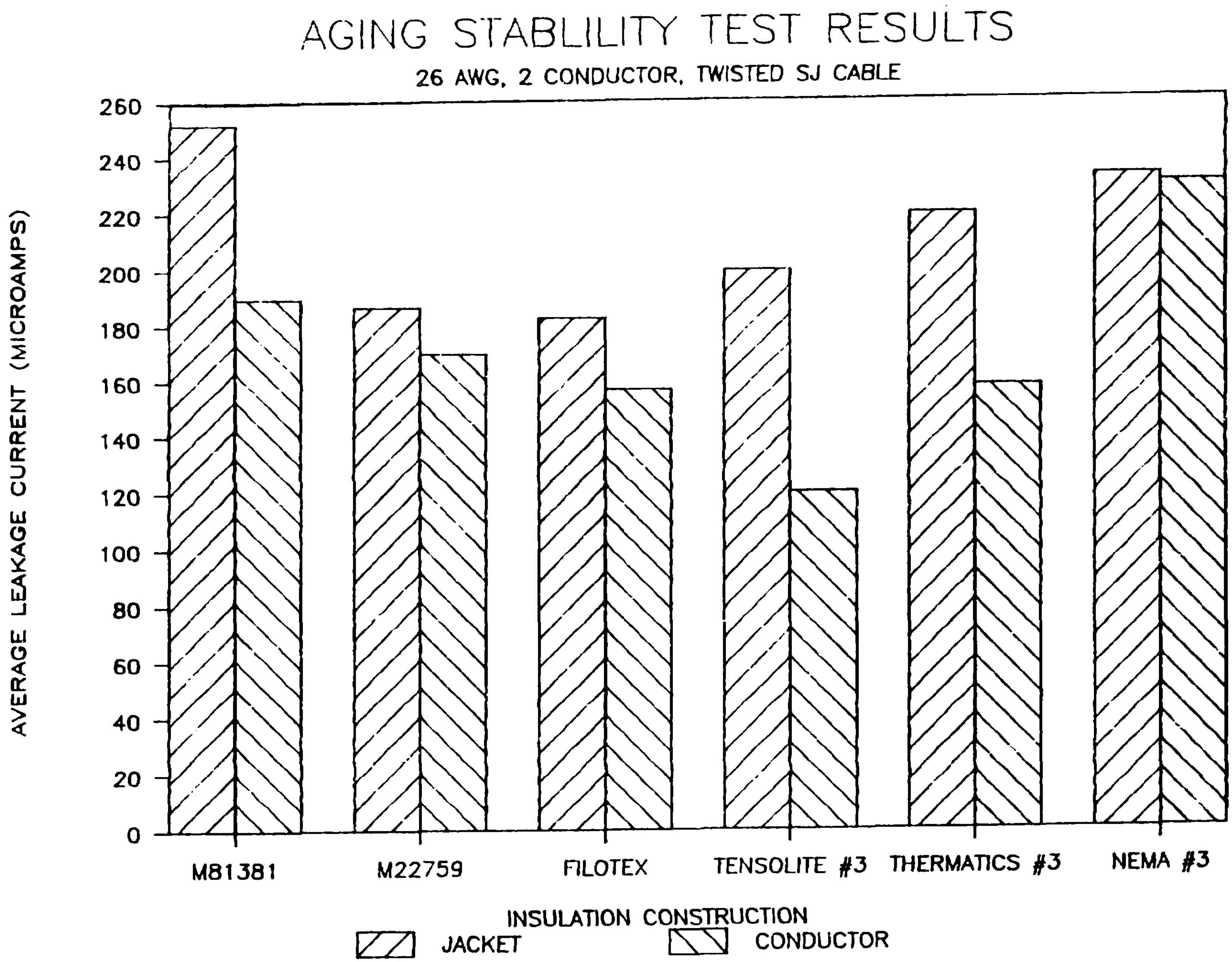


FIGURE 5.87 - AGING STABILITY TEST RESULTS, 26AWG, 2 CONDUCTOR, TWISTED SJ CABLE

FIGURE 5.88 - AGING STABILITY TEST SETUP

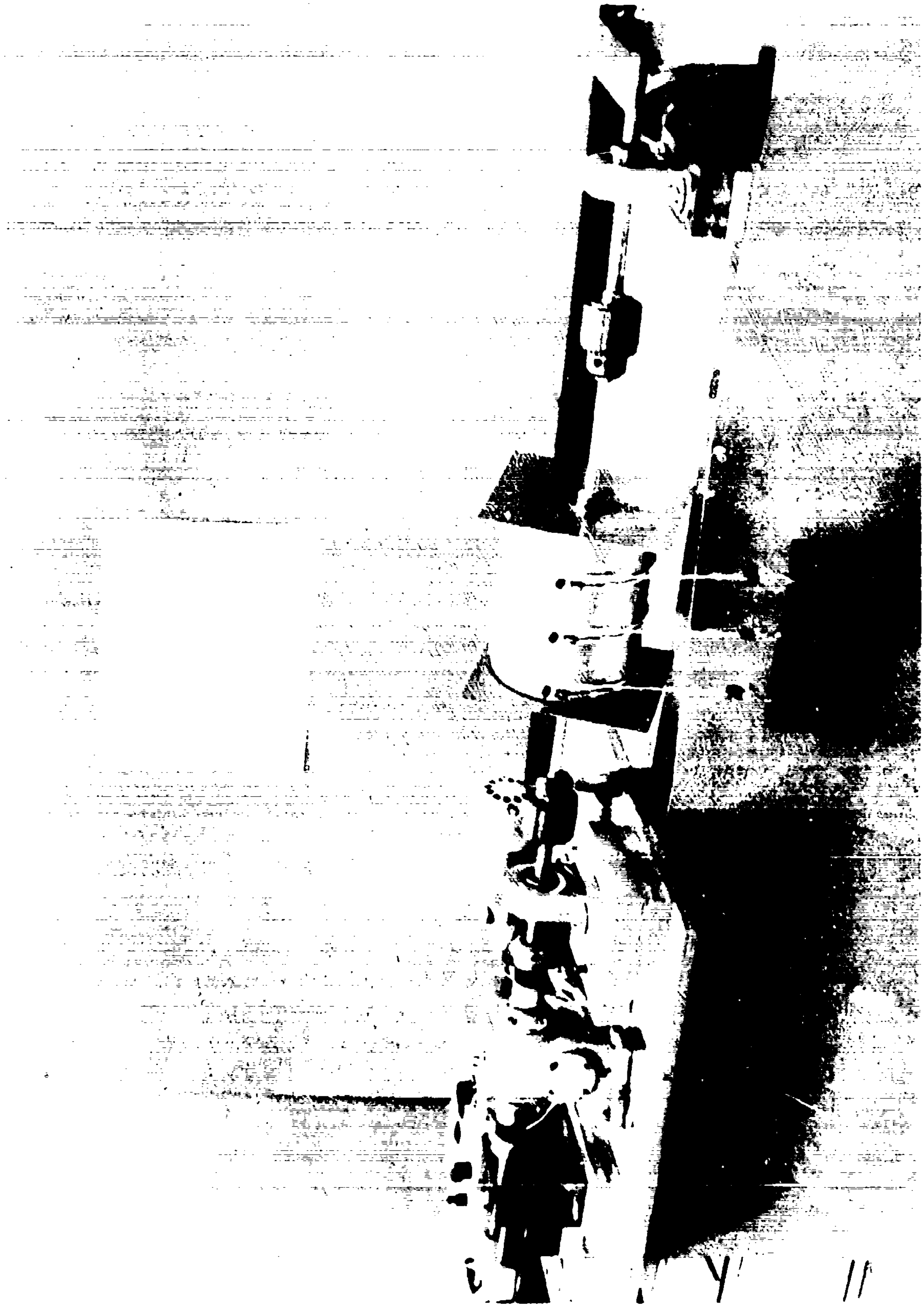


FIGURE 5.89 - AGING STABILITY BEND TEST SETUP

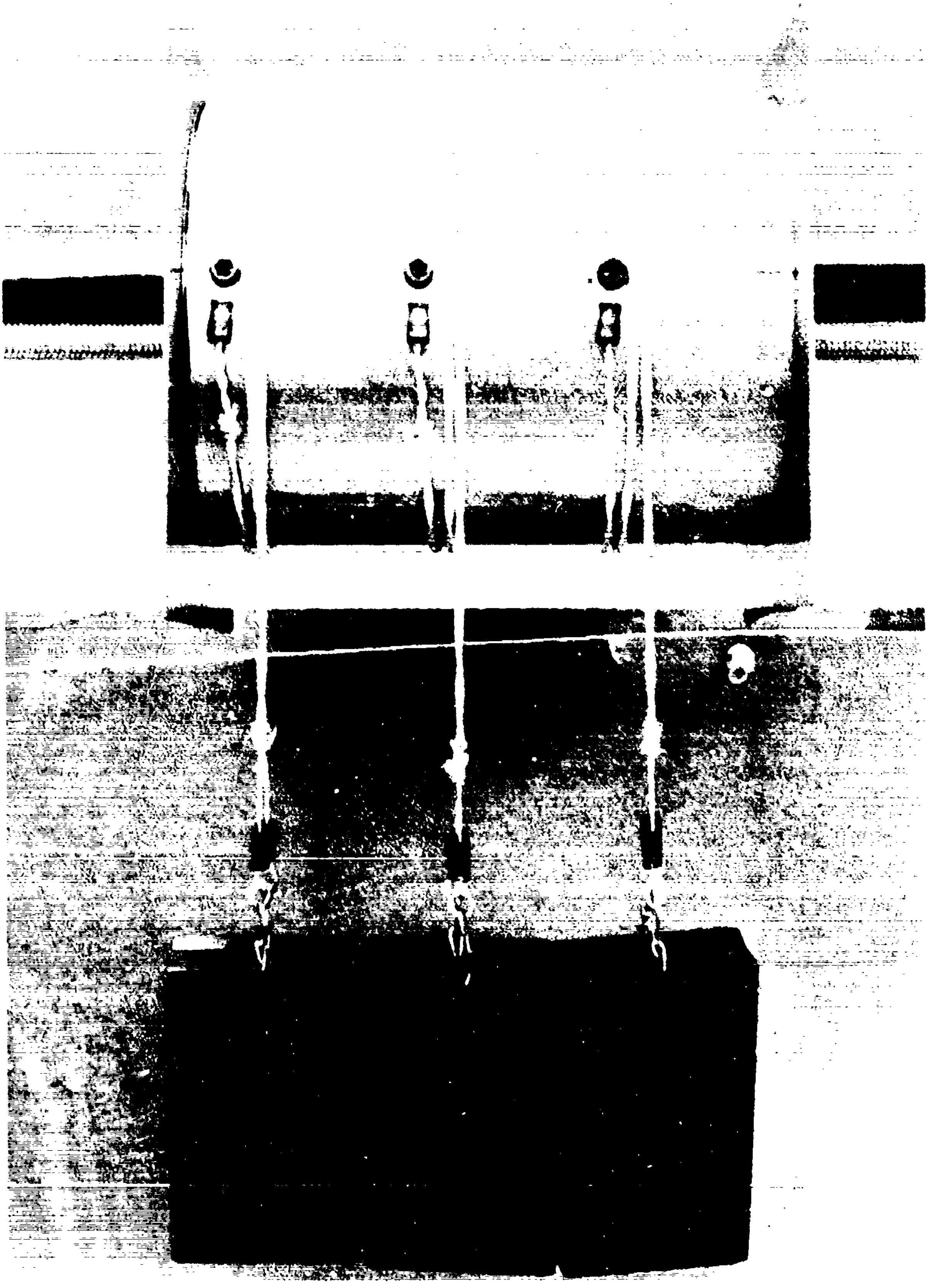


FIGURE 5.90 - AGING STABILITY BEND TEST SPECIMEN CONFIGURATION

5.6.2 SMOKE QUANTITY.

5.6.2.1 Scope: The Smoke Quantity Test was used to determine the quantity of smoke generated from a finished insulated wire when simultaneously exposed to radiant heat and to flame for a 20 minute test period.

5.6.2.2 Reference Procedure: The Smoke Quantity Test was conducted by Douglas Aircraft Company (DAC) according to Method 803 of SAE AS4373. This method references ASTM F 814 for specimen fabrication, test equipment, and procedure.

5.6.2.3 Specimens: Specimens were constructed for 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; 26 gauge, 5.8 mil wall, hook up wire; 22 gauge, two conductor, twisted, shielded and jacketed cable; and 26 gauge, two conductor, twisted, shielded and jacketed cable. Three specimens of each sample were cut to a length of 10 feet. The specimens were conditioned at 21±3°C (70±5°F) and 50±5% relative humidity for a minimum of 24 hours prior to testing the individual specimen.

5.6.2.4 Test Equipment: A Newport Scientific Smoke Density Chamber was used to conduct the Smoke Quantity Tests. The test chamber, radiant heat furnace, specimen holder and frame, photometric system, radiometer, burner,

manometer, and instrumentation conformed to ASTM F 814, section 6. The chamber was cleaned periodically. The surfaces of the photometric system were cleaned after each test. The chamber was calibrated prior to any testing according to the procedure described in Section A1 of ASTM F 814.

5.6.2.5 Test Procedure: A specimen was removed from the preconditioning chamber and wrapped around the specimen frame. The specimen turns were wrapped adjacent to one another with the specimen ends securely fastened to the specimen frame. A layer of aluminum foil, with the dull side of the foil facing the specimen, was placed on the specimen frame prior to wrapping the specimen around the frame. The specimen and frame were placed into the specimen holding fixture, an alumina-silica backing board was placed against the specimen and frame, and held together by a spring plate and rod.

The chamber wall temperature was preheated to 35±2°C (95±4°F). The light transmission reading was adjusted to read 100%. A dummy specimen holding fixture was placed inside the chamber to properly position the pilot burner and adjust the flamelets to the required height. After the flame was ignited and adjusted, the dummy specimen holding fixture was removed and the actual test specimen holding fixture was inserted. The chamber was immediately sealed and the data recording device and

timer were initiated to record the data. The percent of light transmission versus time was recorded with a minimal sample rate of five seconds. The chamber pressure was monitored by the manometer and checked for negative pressure. If negative pressure was observed, a pressure relief valve was opened to stabilize the pressure. The furnace voltage was monitored to ensure that the proper radiance level on the specimen was maintained. The test was continued for 20 minutes. At completion of the 20 minute test period, the burners were extinguished and a vent was opened to exhaust the smoke from the chamber. When all the smoke was exhausted from the chamber, the chamber was cleaned from remaining debris and the photocell and light source were cleaned with a non-abrasive agent. After the cleaning, the chamber was prepared for the next test specimen.

The data acquired from the test was reduced to determine the Specific Optical Density of the specimen. Specific Optical Density (Ds) was defined as an optical measurement of the amount of smoke produced per unit area by a material during combustion. The Specific Optical Density was calculated as follows:

$$D_s = (V / (L A)) \log_{10} (100 / T)$$

$$D_s = 132 \log_{10} (100 / T)$$

where:

D_s = Specific optical density

V = chamber volume (cubic meters)

L = light path length (meters)

A = exposed specimen area (square meters)

T = minimum percent light transmission

20 minutes

The individual, as well as the average, of the three Specific Optical Densities were calculated and reported.

5.6.2.6 Test Results: The average specific optical density of each sample at completion of the 20 minute tests is presented in Tables 5.83 through 5.87 with graphical representation of the data presented in Figures 5.91 through 5.92.

TABLE 5.83 - SMOKE QUANTITY TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE SPECIFIC OPTICAL DENSITY (D_s) (20 MINUTES)
101	M81381	1.0
106	M22759	170.3
136	FILOTEX	3.0
141	TENSOLITE #3	1.7
146	THERMATICS #3	1.3
156	NEMA #3	49.3

TABLE 5.84 - SMOKE QUANTITY TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE SPECIFIC OPTICAL DENSITY (D_s) (20 MINUTES)
102	M81381	1.0
107	M22759	109.7
137	FILOTEX	0.7
142	TENSOLITE #3	1.3
147	THERMATICS #3	1.0
157	NEMA #3	28.7

TABLE 5.85 - SMOKE QUANTITY TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE SPECIFIC OPTICAL DENSITY (D_s) (20 MINUTES)
103	M81381	1.0
108	M22759	47.3
138	FILOTEX	1.0
143	TENSOLITE #3	3.3
148	THERMATICS #3	1.0
158	NEMA #3	21.0

TABLE 5.86 - SMOKE QUANTITY TEST RESULTS ON 22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE SPECIFIC OPTICAL DENSITY (D_s) (20 MINUTES)
104	M81381	3.3
109	M22759	44.7
239	FILOTEX	1.0
144	TENSOLITE #3	4.7
149	THERMATICS #3	0.3
159	NEMA #3	18.7

TABLE 5.87 - SMOKE QUANTITY TEST RESULTS ON 26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	AVERAGE SPECIFIC OPTICAL DENSITY (D_s) (20 MINUTES)
105	M81381	2.7
110	M22759	48.0
240	FILOTEX	1.0
145	TENSOLITE #3	2.7
150	THERMATICS #3	1.3
160	NEMA #3	505.3

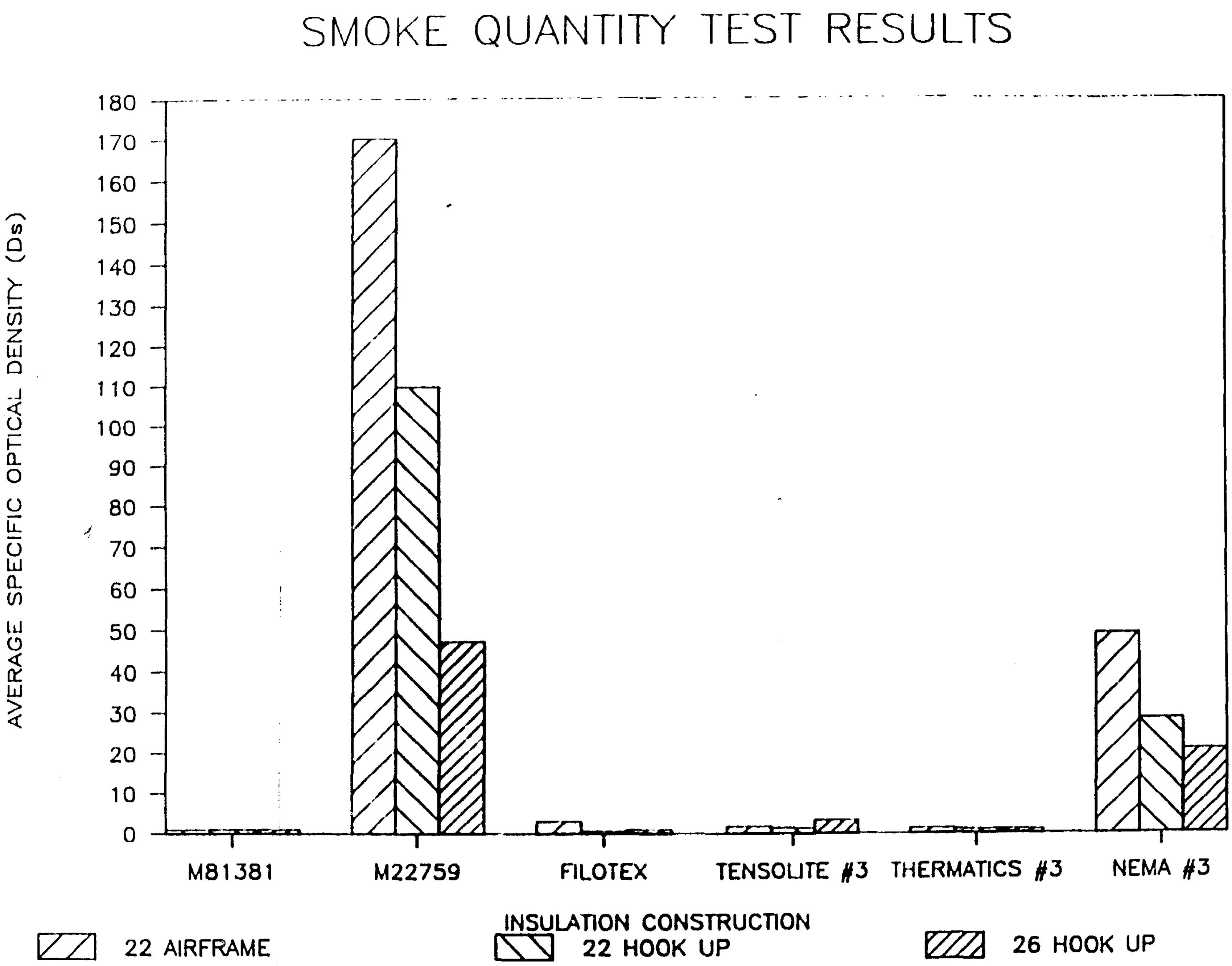


FIGURE 5.91 - SMOKE QUANTITY TEST RESULTS

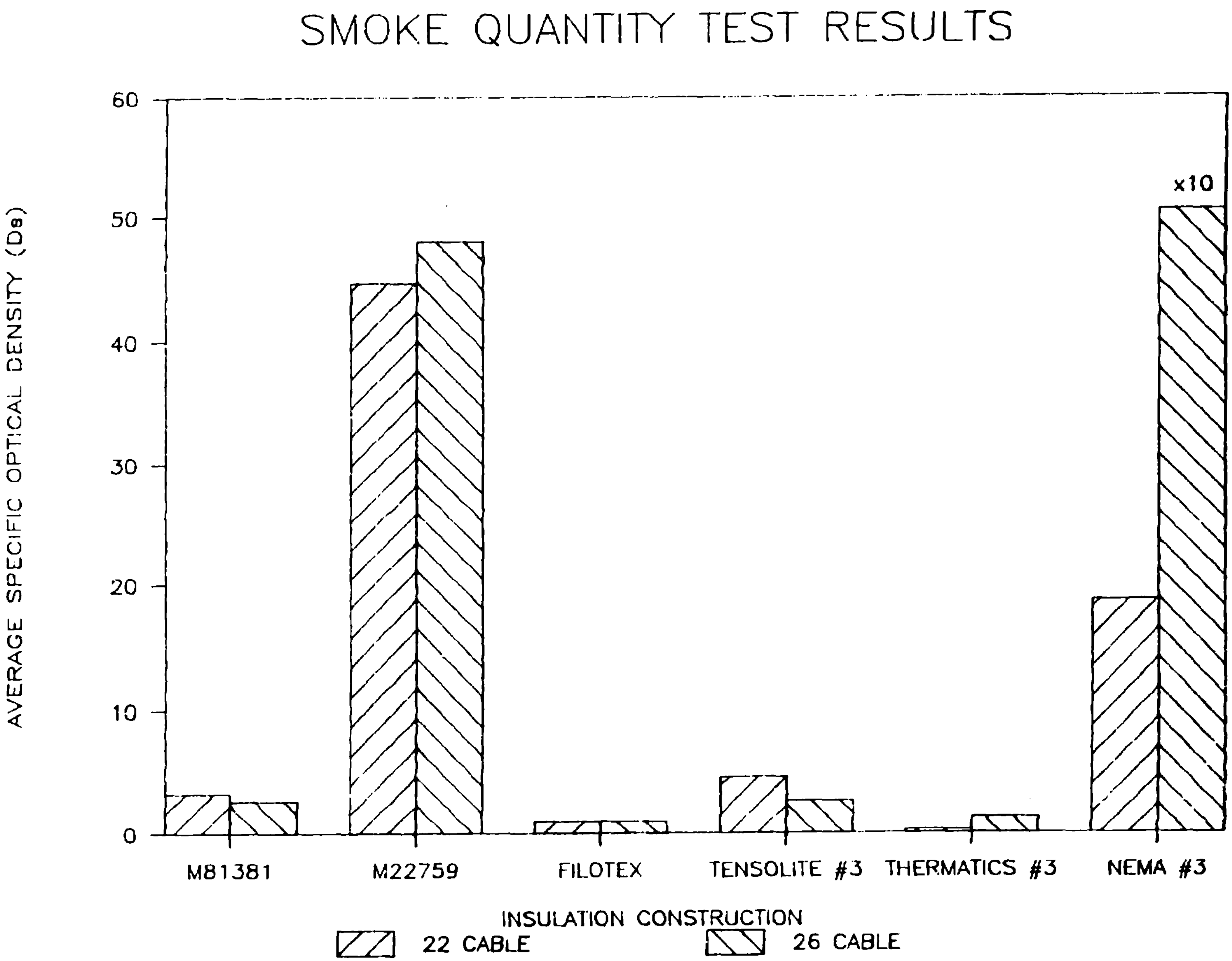


FIGURE 5.92 - SMOKE QUANTITY TEST RESULTS

5.6.3 THERMAL INDEX.

5.6.3.1 Scope: The Thermal Index Test was used to determine life versus temperature curves and temperature indices of finished insulated wire systems.

5.6.3.2 Reference Procedure: The Thermal Index Test was performed by the E.I. Dupont Company according to Method 804 of SAE AS4373. Method 804 references ASTM D3032, section 14, for test equipment and procedures.

5.6.3.3 Specimens: Specimens were prepared for 22 gauge, 8.6 mil wall, airframe wire and 22 gauge, 5.8 mil wall, hook up wire. Eight specimens of each sample of wire were cut to a length of 14 inches for each test temperature. Four temperatures were used resulting in a total of 32 specimens per sample of wire. The specimens had a 0.25 inch segment of insulation removed and the conductor terminated with ring terminals on both ends.

5.6.3.4 Test Equipment: Four air circulating ovens, conforming to the equipment specifications in ASTM D2436, were used for the elevated temperatures. The ovens were instrumented with thermocouples to acquire temperature measurements.

A 0.5 inch mandrel was manufactured for the wrapping segment of the test. A 0.5 pound weight was used to apply tension to the specimen during wrapping.

A dielectric tester was used to conduct a Voltage Withstand Test of 1500 volts at 60 Hertz. The dielectric tester was preset to ramp up to the test potential at a rate of 500 volts per second. A timer was set to apply the test potential to the specimen for one minute.

5.6.3.5 Test Procedure: Eight specimens of each wire sample were suspended by their ring terminals in one of four ovens and held vertically by weights. The ovens were set for temperatures of 220°C (428°F), 240°C (464°F), 260°C (500°F), and 280°C (536°F). The specimens were thermally aged and periodically checked for failures by conducting a Bend Test and a Voltage Withstand Test.

At the pre-selected time interval, the specimens were removed from the specified oven and allowed to cool to room temperature. After the specimen cooled to room ambient, the specimen was attached to a 0.5 inch mandrel on one end while the other had a half pound weight attached to apply tension during wrapping. The specimen was then wrapped in one direction for the specimen's full length and then in the opposite direction for a reverse wrap, comprising one cycle. The wrap was conducted once more for a total of two cycles. The rate of wrapping was 1 revolution every 4±1 second. The specimen was allowed

to twist freely during the wrapping but was not allowed to wrap upon itself. The specimen was removed from the mandrel and subjected to a Voltage Withstand Test.

The Voltage Withstand test was conducted by submersing the straight specimens to within one inch of their ends in a 1% salt (NaCl) solution for a period of one hour. After the completion of the soak period, a potential of 1500 volts at 60 Hertz was applied between the specimen conductor and the solution for a period of one minute unless a failure occurred. A failure was defined as a specimen having a leakage current greater than 10 milliamps. If the specimen failed the Voltage Withstand Test, the total number of hours the specimen was thermally aged was recorded and the specimen removed from from the test sequence. The remaining specimens were rinsed in tap water and returned to the appropriate oven.

The tests were all conducted in the same manner for the four different elevated temperatures. The difference between the tests was the time at which the Voltage Withstand Test was conducted. The specimens thermally aged at 220°C (428°F) were checked for failures every three weeks. The specimens thermally aged at 240°C (464°F) were checked for failures every two weeks. The specimens thermally aged at 260°C (500°F) were checked for failures every week. The specimens thermally aged at 280°C (535°F) were checked for failures every three days.

The data acquired was accumulated and the average life was calculated from the first five specimens to fail the Voltage Withstand test. The average life value was computed as follows:

$$\text{Average Life} = \log_{10}^{-1} \{[\log_{10}(t_1) + \ldots + \log_{10}(t_5)] / 5\}$$

$t_1, \ldots, t_5$ = total time exposed to thermal aging to fail Voltage Withstand Test.

Graphs of the temperature versus hours to 50% failure were calculated for specimens having at least two data points.

5.6.3.6 Test Results: The 50% failure calculations of the specimens are presented in Tables 5.88 through 5.91, and the actual test hours versus failures are shown in Tables 5.92 through 5.95. Also graphs of the temperature versus hours to 50% failure are included in Figures 5.93 through 5.99. Results of samples with less than two measured data points are not plotted.

E. I. DUPONT'S COMMENTS ON THERMAL INDEX TESTS

The test method that was used is based on ASTM D3032 but it deviates from standard D3032 in several ways. (A) The standard test procedure requires pretesting of each sample to determine the appropriate time length of the test cycles for that material. This was not done in the CRAD test because it was the intent that all sample should be tested exactly the same way (i.e., using the same cycle times and temperatures). This resulted in testing apples, oranges, peaches and pears as "fruit". The samples turned out to be so different in thermal life that some samples failed after relatively few cycles and are probably over rated by the test, while other samples went well beyond the recommended maximum of ten cycles and therefore are over stressed by cycling and are probably under rated by the test. The test method assumes that the cycle time for each material is setup to fail in 5-10 cycles but should not run more than 10 cycles. Also remember that the test was setup with 12 total samples of which 6 were dropped after the screening tests. Some of these also failed in the first few cycles.

The tables provided in the regular reports do not make the total cycles readily apparent. For that reason the attached alternate tables are provided for each test temperature. These (Tables 5.92 through 5.95) show each test cycle even when there were no failures at the end of

a particular cycle time and they (Tables 5.88 through 5.91) show calculations of average 50% failure times. Using these tables, any sample that has significant failures on the first few cycles obviously could have a significantly lower thermal index because the first samples may have actually failed at the beginning of the recorded cycle time which is a large relative difference from half way through the cycle time. Samples that failed mostly in the 5th through the 10th cycles are most likely to give accurate results. Additionally note that the samples that have more than 10 cycles (which includes part of the final candidates constructions) may be over stressed by thermal cycling and are probably better than the test results will indicate when the tests are finally done. This test error may be insignificant since it only means that the results are conservative and the samples have excellent thermal ratings anyway.

The second test method variation is the wire samples that were used. The standard procedure recommends the use of 20 AWG or 14 AWG wire. The CRAD program used 22 AWG wires. I doubt that this significantly affected results.

The third variation is the weights that were used for the wires while in the oven and for the mandrel wrapping at each cycle are different than standard. The weights recommended for mandrel wrapping 22 AWG wires (as found in the Appendixes of D3032) are 0.88 lbs and the weights

for holding the wires straight while hanging in the ovens are recommended as approximately half of the above weights. The weights that were actually used were 0.5 lbs for all samples for both hanging and wrapping.

This variation may be the reason that several specimens had conductor breakage at the crimp point where the ring terminals were put on to support the weights. Because the conductor breaks were not considered an indication of insulation failure and the wires were passing the dielectric test the samples were continued in the test after having new ring terminals attached as long as the samples were long enough to allow the mandrel bending and dielectric tests. However, some samples were eliminated for this reason. In reviewing the notebook records I find that samples are sometimes noted to have had the weights "dropping". This indicates to me that the conductor was being elongated by the excess weight. This may place a bias on the results since the various insulations will support different amount of this stress. Some constructions will have the insulation carrying a lot of the stress once the conductor has significant strain. With other constructions the insulations will not carry significant stress even if the conductor elongates a significant amount.

The next variation is that we did not have enough wire to use 10 specimens for each set. We did use 8 and this slightly reduces the accuracy of the results.

Finally, in an ideal situation all specimens would be tested until you have firm data points for the 50% failure for at least 3 temperatures. Since several of the constructions had such excellent thermal life that this did not happen we have to work with the data points that we have. This means that a larger uncertainty exists when you try to extrapolate to determine a 10,000 hour or 100,000 hour thermal index.

Typical thermal aging data, when plotted in Arrhenius graphs has similar slopes for most insulations. Graph 1 provides some of this type data showing XLPVC, ETFE (some of the newer grades), MIL-W-81044/9, MIL-W-81381/12, and PTFE wires. Some of this data has been published by Dave Elliot and by DuPont. If a wire fails by a different mechanism it could have a significantly different slope but typical aerospace wire insulations have normally fit the trend/slope fairly well.

With some of the candidates in the CRAD where we have only one data point completed the slope could be assumed and the continuing aging studies would say that the final failures may prove this out but haven't yet done so.

Where we have only two data points, the slopes are not very close to the typical so I would not feel comfortable extrapolating this data outside the range of the data points, even to 15,000 hrs.

The results, while technically a significant variation of D3032 methods, should be valid for the intended purpose which was to relatively rank the candidates and controls. Once a construction has been chosen it may be appropriate to run the D3032 test procedure for that construction adjusting the cycle times and weights so as to ideally test that particular construction.

TABLE 5.88 - 50 PERCENT FAILURE CALCULATIONS

Spool No.	Failure Times and Number of Samples	#	Test Temperature 220C	240C	260C	280C	
146	None		NA				
	None			NA			
	2731	1			2731		
	1923 1995 2141 2218	4 2 1 1				2005 2002	Straight Average D3032 Log Method
101	None		NA				
	None			NA			
	3065 3230 3401 3573	1 1 2 4			3424 3419		Straight Average D3032 Log Method
	1778 1851 1923 2067	3 1 2 2				1895 1892	Straight Average D3032 Log Method
106	None		NA				
	1498	8		1498 1498			Straight Average D3032 Log Method
	252 420	1 7			399 394		Straight Average D3032 Log Method
	107 179	4 4				143 138	Straight Average D3032 Log Method

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TABLE 5.89 - 50 PERCENT FAILURE CALCULATIONS

Spool No.	Failure Times and Number of Samples	#	220C	240C	260C	280C	
156	None		NA				
	2472	1		3526			Straight Average
	3677	7		3499			D3032 Log Method
	1732	7			1754		Straight Average
	1909	1			1753		D3032 Log Method
	709	2					
	824	4				827	Straight Average
	904	1				822	D3032 Log Method
	995	1					
141	None		NA				
	1498	1		NA			
	None				NA		
	1695	7					
	1851	1				1714	Straight Average
						1714	D3032 Log Method
136	None		NA				
	None			NA			
	None				NA		
	1995	1					
	2067	1				2198	Straight Average
	2141	1				2195	D3032 Log Method
	2218	3					
	2364	2					

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TABLE 5.90 - 50 PERCENT FAILURE CALCULATIONS

Spool No.	Failure Times and Number of Samples	#	Test Temperature 220C	240C	260C	280C	
107	3796	8	3796				Straight Average
			3796				D3032 Log Method
	826	8		826			Straight Average
				826			D3032 Log Method
	252	8			252		Straight Average
					252		D3032 Log Method
	107	8				107	Straight Average
						107	D3032 Log Method
102	None		NA				
	3677	3			4118		Straight Average
	4181	2			4102		D3032 Log Method
	4517	3					
	1556	1				1821	Straight Average
	1732	2				1816	D3032 Log Method
	1909	5					
	1297	6				1325	Straight Average
	1409	2				1324	D3032 Log Method
137	None		NA				
	None			NA			
	3065	2			NA		
	107	1					
	1602	1				1773	Straight Average
	1695	1				1385	D3032 Log Method
	2067	1					
	2141	3					
	2292	1					

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TABLE 5.91 - 50 PERCENT FAILURE CALCULATIONS

Spool No.	Failure Times and Number of Samples	No.	Test Temperature 220C	240C	260C	280C	
157	3796	1					
	4299	5	4361				Straight Average
	4801	2	4351				D3032 Log Method
	1498	1					
	1833	5		1871			Straight Average
	2153	2		1861			D3032 Log Method
	920	2					
	1088	5			1066		Straight Average
	1251	1			1062		D3032 Log Method
	393	1					
	464	4				482	Straight Average
	535	3				479	D3032 Log Method
147	4801		NA				
	None			NA			
	2898	1			3234		Straight Average
	3065	1			3223		D3032 Log Method
	3401	1					
	3573	1					
	1511	1				1699	Straight Average
	1602	2				1696	D3032 Log Method
	1695	1					
	1778	3					
	1851	1					
142	None		NA				
	None			NA			
	3065				NA		
	1923	2					
	2067	1				2133	Straight Average
	2141	2				2128	D3032 Log Method
	2218	1					
	2292	1					
	2384	1					

GP13-0123-10-D

TABLE 5.92 - THERMAL INDEX TEST RESULTS AT 220°C

THERMAL INDEX TEST RESULTS - 220°C

Hours	146	101	106	156	141	136	107	102	137	157	147	142
530.5												
1034												
1538												
2039												
2535												
3040												
3544												
4048							8			1		
4549										5		
5052										2	1	
5558												
6062												
Remaining Samples	8	8	8	8	8	8	0	8	8	0	7	8

GP13-0123-3-D/suz

TABLE 5.93 - THERMAL INDEX TEST RESULTS AT 240°C

THERMAL INDEX TEST RESULTS - 240°C

Hours	146	101	106	156	141	136	107	102	137	157	147	142
330.5												
658												
994							8					
1330												
1665			8		1					1		
2000										5		
2306										2		
2637				1								
3007												
3341												
4013				7				3				
4349								2				
4685								3				
5013												
5546												
5877												
6218												
Remaining Samples	8	8	0	0	7	8	0	0	8	0	8	8

GP13-0123-4-D/suz

TABLE 5.94 - THERMAL INDEX TEST RESULTS AT 260°C

THERMAL INDEX TEST RESULTS - 260°C

Hours	146	101	106	156	141	136	107	102	137	157	147	142
168												
336			1				8					
504			7									
670												
836												
1004										2		
1171										5		
1331										1		
1475												
1636								1				
1828				7				2				
1989				1				5				
2158												
2321												
3482												
2646												
2815	1											
2981											1	
3149		1							2		1	1
3311		1										
3491		2									1	
3654		4									1	
Remaining Samples	7	0	0	0	8	8	0	0	6	0	4	7

GP13-0123-5-D/suz

TABLE 5.95 - THERMAL INDEX TEST RESULTS AT 280°C

THERMAL INDEX TEST RESULTS - 280°C

Hours	146	101	106	156	141	136	107	102	137	157	147	142
71												
143			4				8		1			
214			4									
286												
358												
428										1		
500										4		
569										3		
638												
780				2								
868				4								
939				1								
1051				1								
1145												
1241												
1353								6				
1465								2				
1556											1	
1647									1		2	
1742					7				1		1	
1814		3									3	
1887		1			1						1	
1959	4	2										2
2031	2					1						
2102		2				1			1			1
2179	1					1			3			2
2256	1					3						1
2328									1			1
2400						2						1
Remaining Samples	0	0	0	0	0	0	0	0	0	0	0	0

GP13-0123-6-D/suz

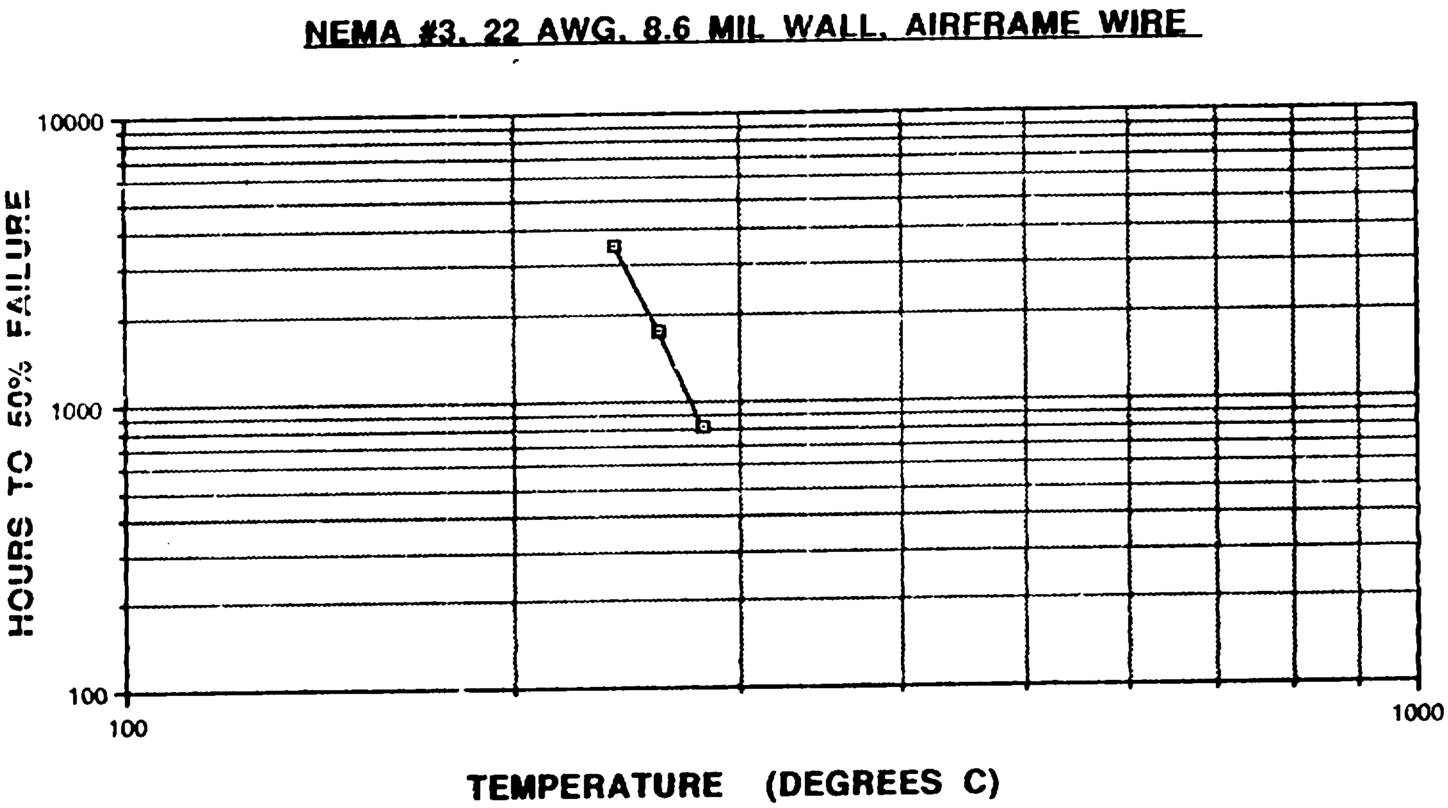

FIGURE 5.93 - THERMAL INDEX TEST RESULTS, NEMA #3, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

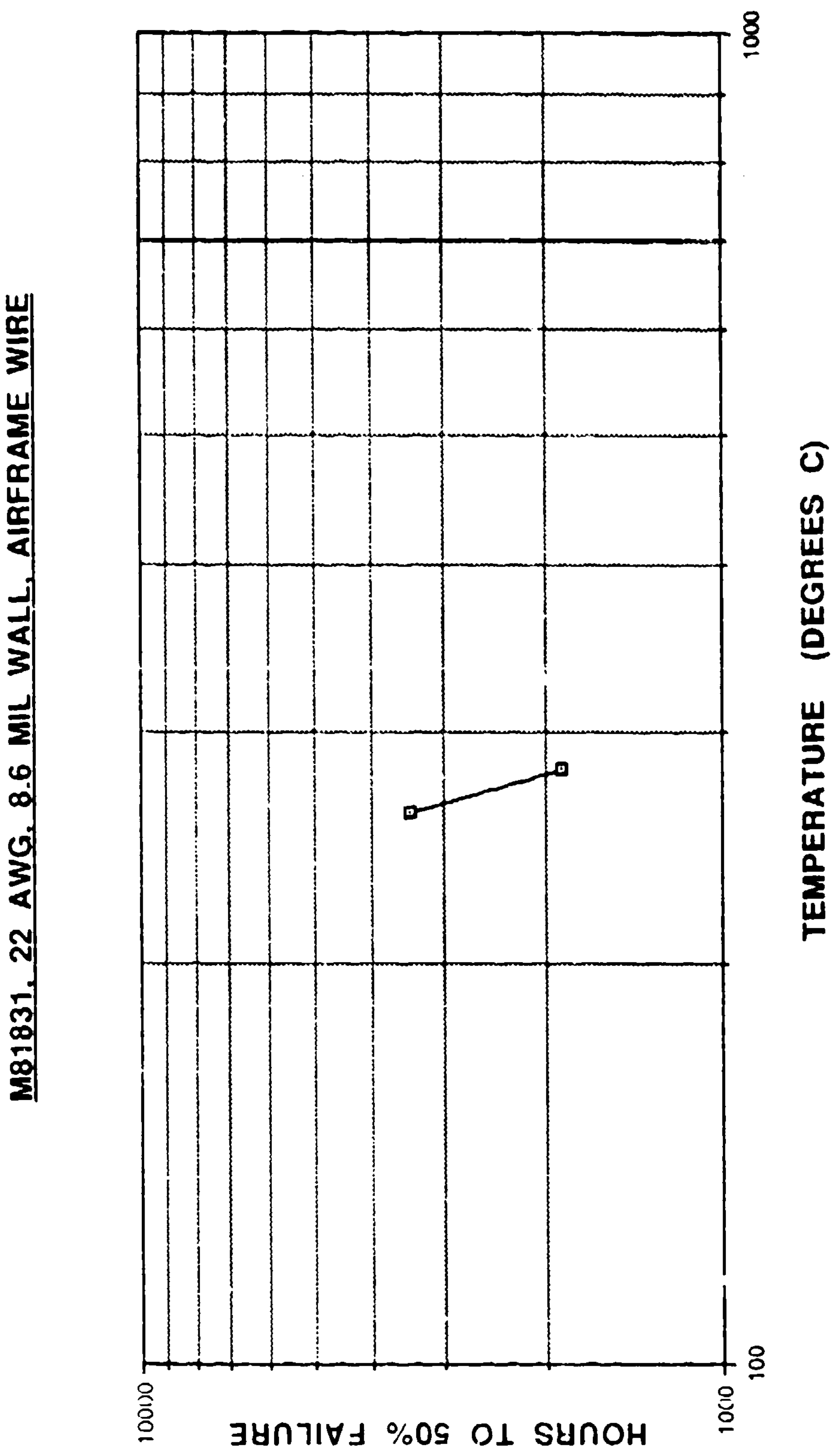

FIGURE 5.94 - THERMAL INDEX TEST RESULTS,
M81381, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

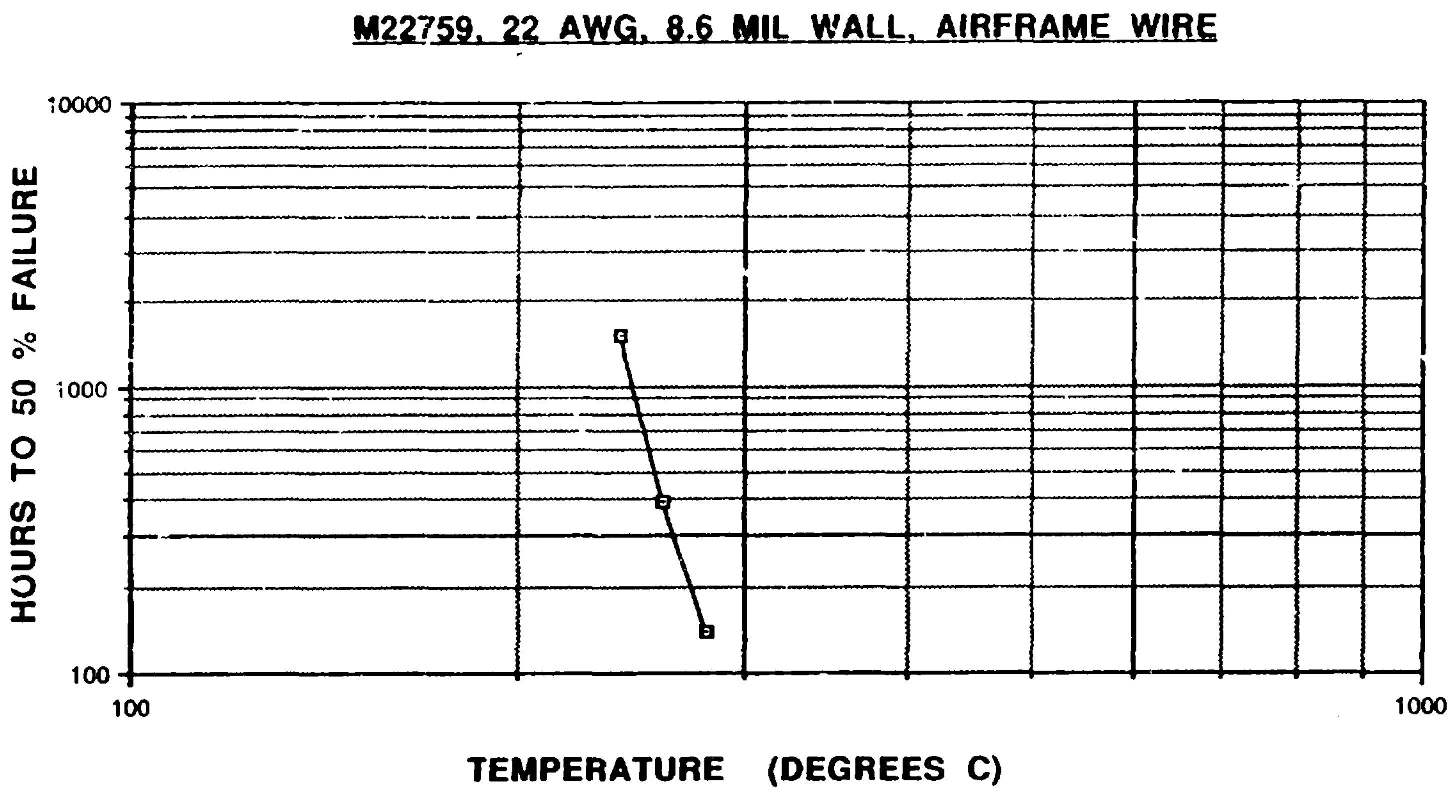

FIGURE 5.95 - THERMAL INDEX TEST RESULTS,
M22759, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

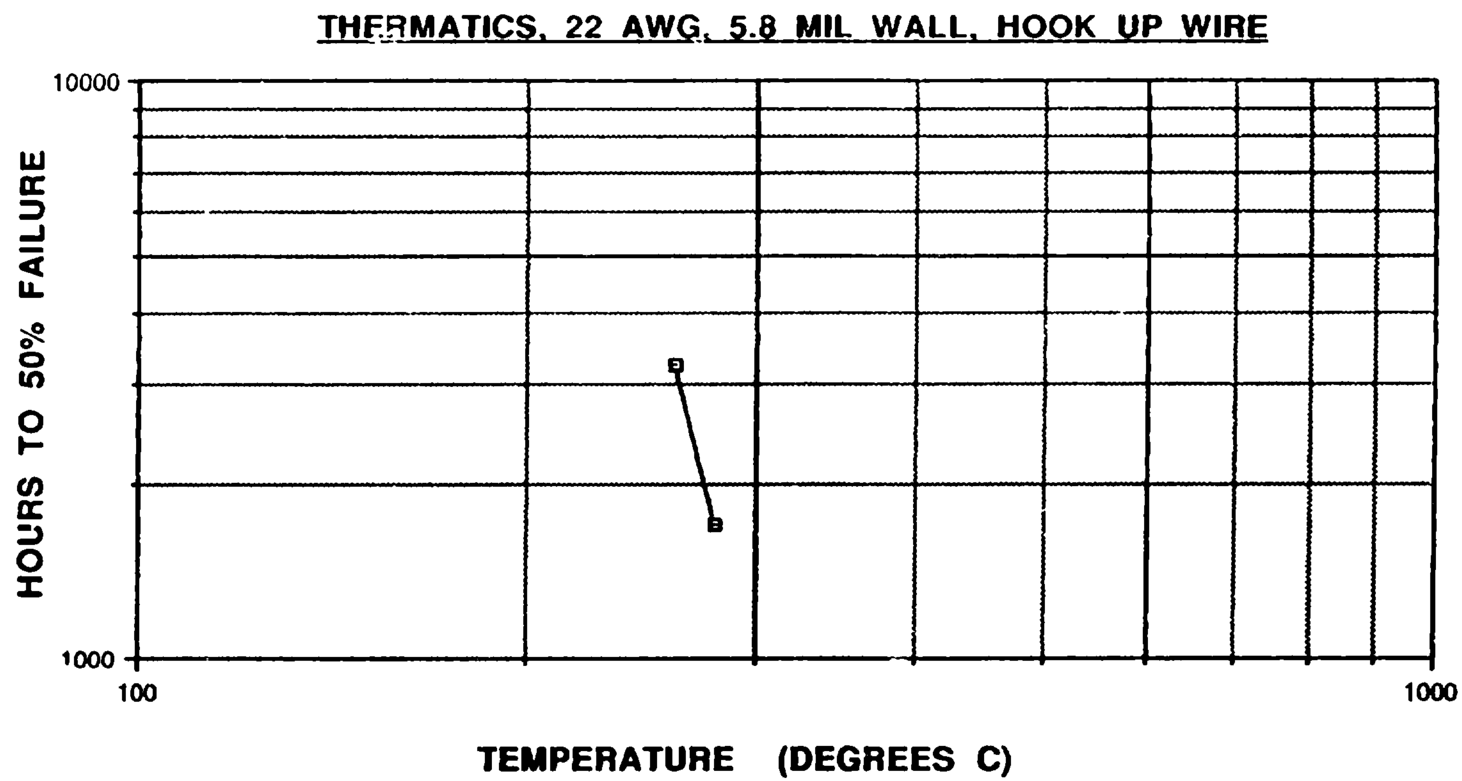

FIGURE 5.96 - THERMAL INDEX TEST RESULTS, THERMATICS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

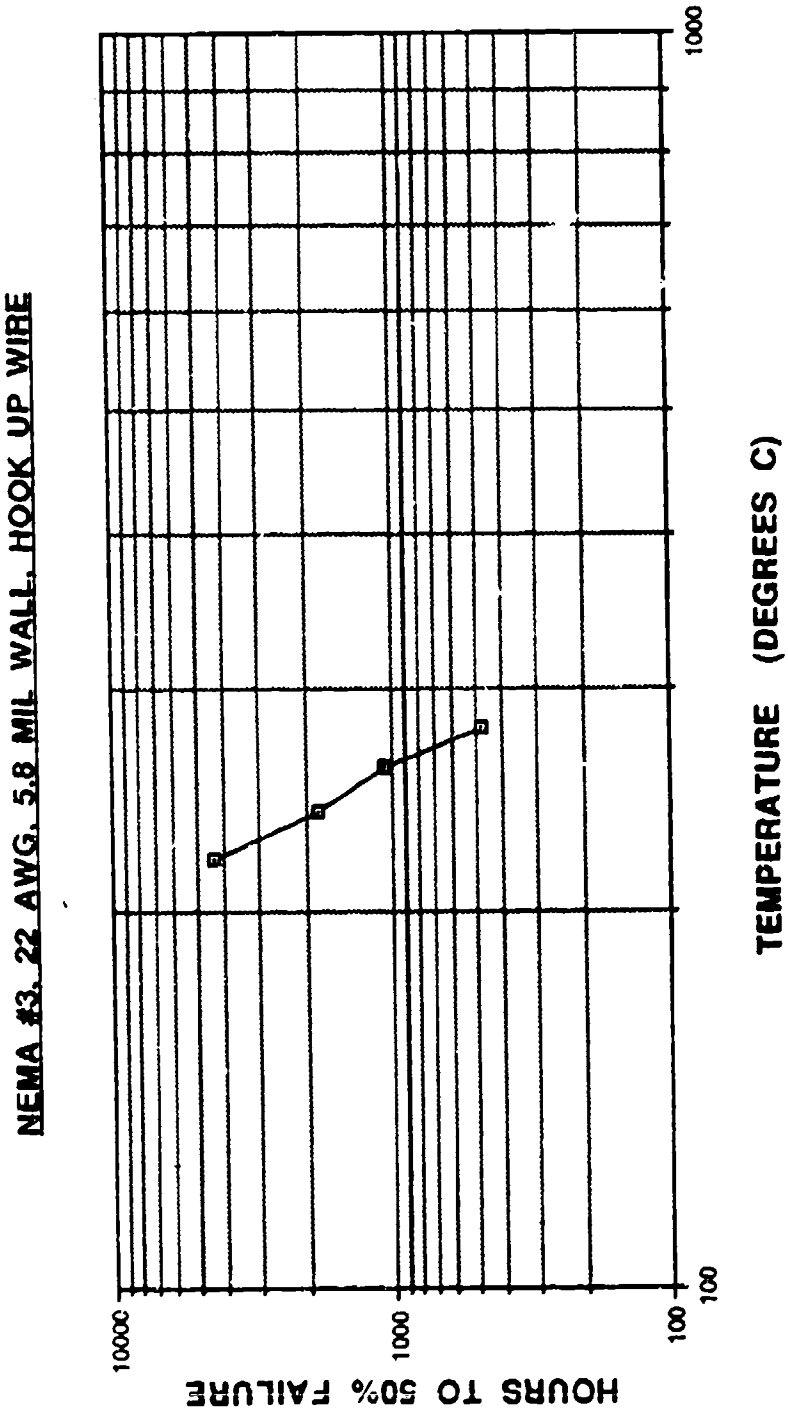

FIGURE 5.97 - THERMAL INDEX TEST RESULTS,
NEMA #3, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

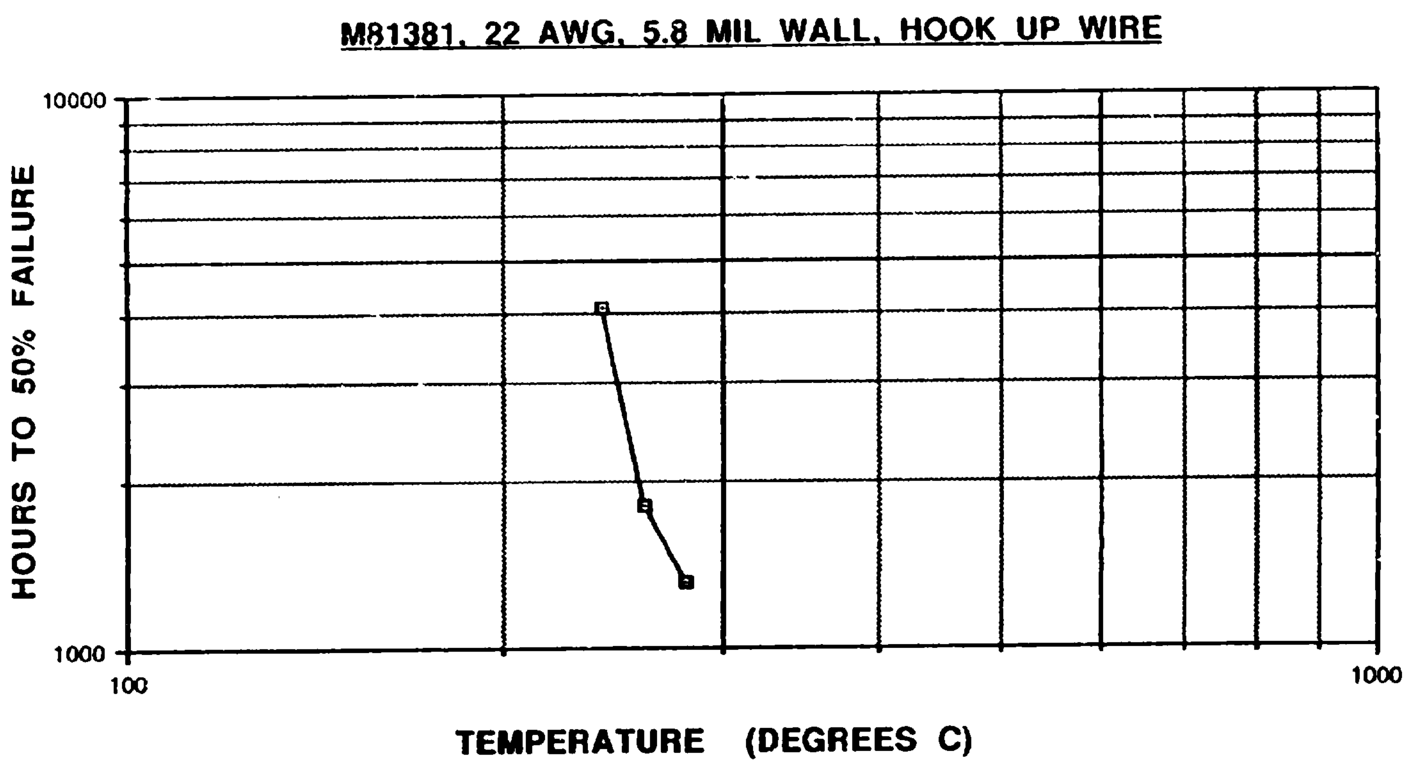

FIGURE 5.98 - THERMAL INDEX TEST RESULTS, M81381, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

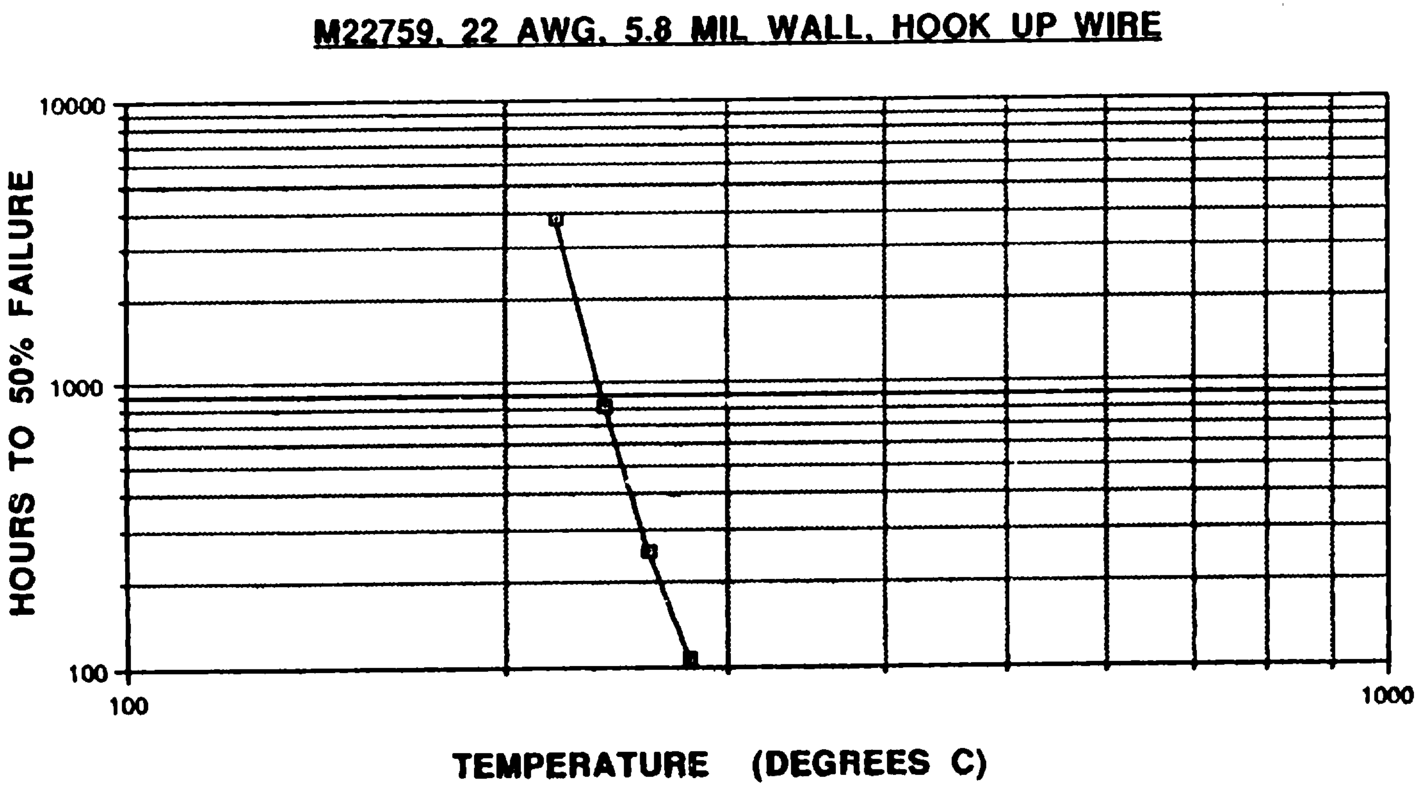

FIGURE 5.99 - THERMAL INDEX TEST RESULTS, M22759, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

5.6.4 **THERMAL SHOCK.**

5.6.4.1 Scope: The Thermal Shock Test was used to evaluate short term shrinkage or expansion on the unconditioned finished wire and cable after thermal shock exposure.

5.6.4.2 Reference Procedure: The Thermal Shock Test was performed according to Method 805 of SAE AS4273. Test Method 805 references ASTM D3032, Section 21, for procedure and test equipment. The test was conducted and measurements were made only before and after the four temperature cycles with no ambient stabilization times between cycles.

5.6.4.3 Specimens: Unconditioned specimens were constructed from 22 gauge, 8.5 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; 26 gauge, 5.8 mil wall, hook up wire; 22 gauge, two conductor, twisted, shielded and jacketed cable; and 26 gauge, two conductor, twisted, shielded and jacketed cable. Six specimens of each sample were cut to a length of 60 inches with ends cut flush. A one inch segment of insulation was removed from both ends of the wire specimens while a one inch segment of the jacket was removed from the ends of the cable specimens. The specimens were looped into eight inch diameter coils and loosely tied with fiberglass (MIL-43435B, type IV) lacing tape to retain the coiled

configuration. The ends of the specimens were identified by marking the lacing tape.

5.6.4.4 Test Equipment: A Delta Design Environmental Chamber (MD 115370) was used for the elevated temperature of 200°C (392°F) and a Delta Design Environmental Chamber (MD 058174) was used for the -55°C (-67°F) temperature. The cold chamber used liquid nitrogen and the chambers internal servo valve to control and maintain the desired temperature of -55°C (-67°F). The chamber's temperatures were monitored using a Fluke Datalogger (MD 084509) with type J thermocouples.

A steel scale ruler with graduations of a 0.01 inches was used to measure the distance from the end of the conductor to the beginning of the insulation. A Bausch and Lomb Microscope (MD 121434) with 20 power magnification was used to assist the technician with acquiring measurements.

Photographs of the chambers and specimens are presented in Figures 5.105 through 5.106.

5.6.4.5 Test Procedure: The exposed ends of the specimens were measured using a steel scale ruler with graduations of 0.01 inches. Each end of the specimen was measured from the edge of the conductor to the edge of the wire insulation or cable jacket. These values were recorded and compared to the post test data values.

The coiled specimens were loosely secured to the rack with fiberglass (MIL-43435B, type IV) lacing tape to minimize specimen movement during transfers. The specimens and rack were placed in a chamber preheated to 200°C (392°F). The specimens remained there for a 30 minute period after the chamber recovered to within ±2°C of the test temperature. After completion of the hot portion of the cycle, the rack and specimens were transferred to a cold chamber at -55°C (-67°F) in less than two minutes. The specimens remained at -55°C (-67°F) for 30 minutes after the chamber recovered to within ±2°C of the test temperature. One thermal shock cycle consisted of a 30 minute exposure to 200°C (392°F) followed by a 30 minute exposure to -55°C (-67°F). Three additional cycles were conducted successively. At the completion of the four thermal shock cycles, the specimens were allowed to return to room temperature before the measurements were taken.

Post thermal shock measurements were taken and compared to the initial measurements for a delta value. The pretest and post-test measurements and calculated delta values were recorded. The specimens were also inspected for flaring of the insulation layers and denoted as a pass (P) or fail (F).

5.6.4.6 Test Results: The average change between the end of conductor and the end of the insulation for the six specimens of each sample was determined and the results are presented in Tables 5.96 through 5.100 with the results of the insulation inspection. Graphical representations of the data are presented in Figures 5.100 through 5.104. All changes measured were contractions of the insulation except Tensolite 145.

TABLE 5.96 - THERMAL SHOCK TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CHANGE (INCHES)	MAXIMUM CHANGE (INCHES)	AVERAGE CHANGE (INCHES)	INSULATION INSPECTION (P / F)
101	M81381	0.00	0.02	0.013	6 / 0
106	M22759	0.00	0.02	0.004	6 / 0
136	FILOTEX	0.00	0.01	0.003	6 / 0
141	TENSOLITE #3	0.00	0.04	0.014	6 / 0
146	THERMATICS #3	0.00	0.10	0.053	6 / 0
156	NEMA #3	0.00	0.01	0.006	6 / 0

TABLE 5.97 - THERMAL SHOCK TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CHANGE (INCHES)	MAXIMUM CHANGE (INCHES)	AVERAGE CHANGE (INCHES)	INSULATION INSPECTION (P / F)
102	M81381	0.00	0.03	0.008	6 / 0
107	M22759	0.00	0.02	0.006	6 / 0
137	FILOTEX	0.00	0.02	0.008	6 / 0
142	TENSOLITE #3	0.00	0.02	0.009	6 / 0
147	THERMATICS #3	0.06	0.12	0.086	6 / 0
157	NEMA #3	0.00	0.01	0.003	6 / 0

TABLE 5.98 - THERMAL SHOCK TEST RESULTS ON
26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CHANGE (INCHES)	MAXIMUM CHANGE (INCHES)	AVERAGE CHANGE (INCHES)	INSULATION INSPECTION (P / F)
103	M81381	0.00	0.02	0.005	6 / 0
108	M22759	0.00	0.01	0.002	6 / 0
138	FILOTEX	0.00	0.00	0.000	6 / 0
143	TENSOLITE #3	0.04	0.15	0.089	6 / 0
148	THERMATICS #3	0.03	0.10	0.066	6 / 0
158	NEMA #3	0.00	0.02	0.007	6 / 0

TABLE 5.99 - THERMAL SHOCK TEST RESULTS ON
22 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CHANGE (INCHES)	MAXIMUM CHANGE (INCHES)	AVERAGE CHANGE (INCHES)	INSULATION INSPECTION (P / F)
104	M81381	0.01	0.08	0.035	6 / 0
109	M22759	0.00	0.08	0.048	6 / 0
239	FILOTEX	0.06	0.08	0.068	6 / 0
144	TENSOLITE #3	0.00	0.12	0.024	6 / 0
149	THERMATICS #3	0.00	0.03	0.021	6 / 0
159	NEMA #3	0.02	0.05	0.025	6 / 0

TABLE 5.100 - THERMAL SHOCK TEST RESULTS ON
26 AWG, 2 CONDUCTOR, TWISTED, SHIELDED AND JACKETED CABLE

SPOOL REF.	INSULATION CONSTRUCTION	MINIMUM CHANGE (INCHES)	MAXIMUM CHANGE (INCHES)	AVERAGE CHANGE (INCHES)	INSULATION INSPECTION (P / F)
105	M81381	0.04	0.07	0.058	6 / 0
110	M22759	0.02	0.06	0.037	6 / 0
240	FILOTEX	0.00	0.02	0.007	6 / 0
145	TENSOLITE #3	-0.02	0.15	0.046	6 / 0
150	THERMATICS #3	0.02	0.05	0.033	6 / 0
160	NEMA #3	0.01	0.11	0.041	6 / 0

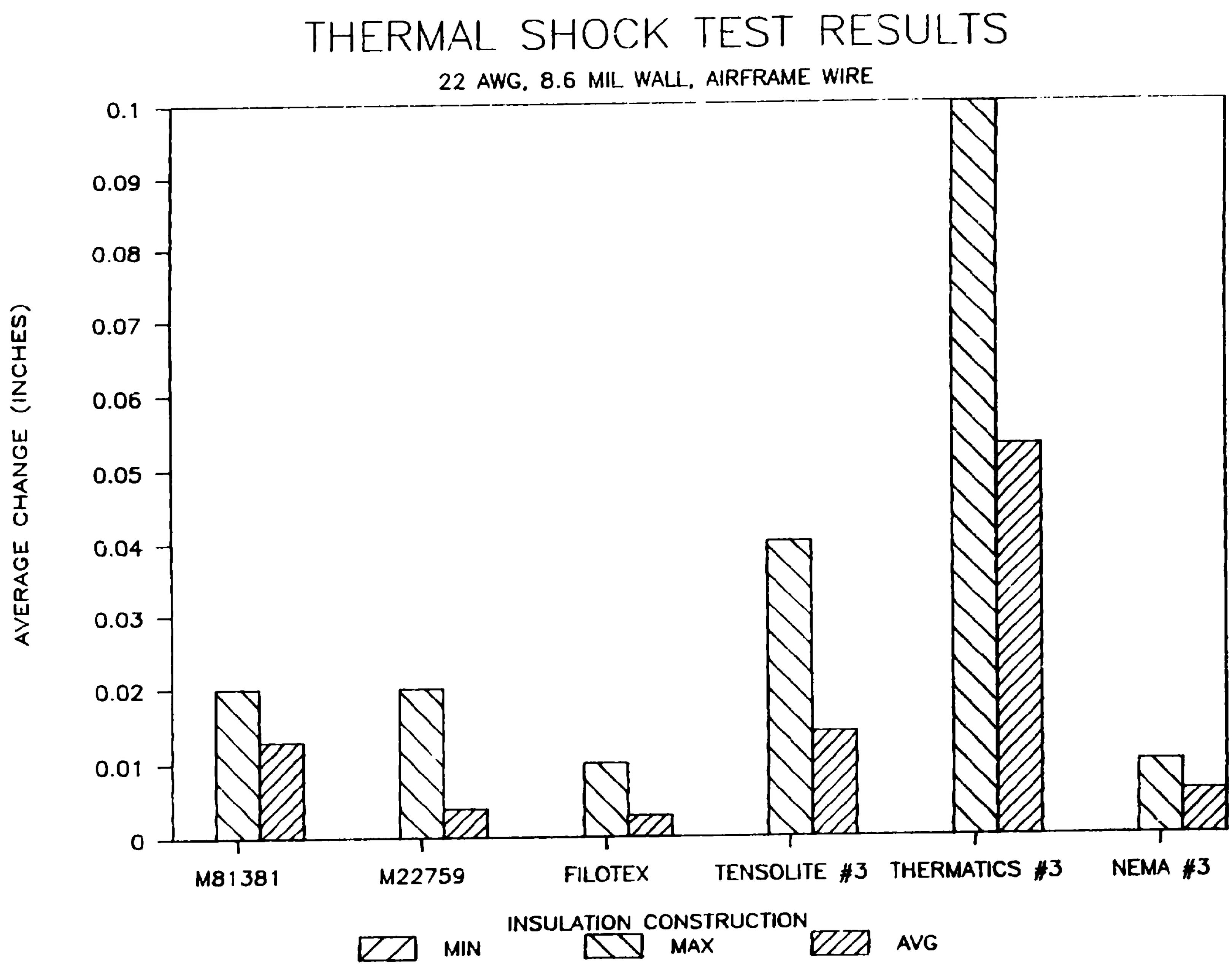

FIGURE 5.100 - THERMAL SHOCK TEST.RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

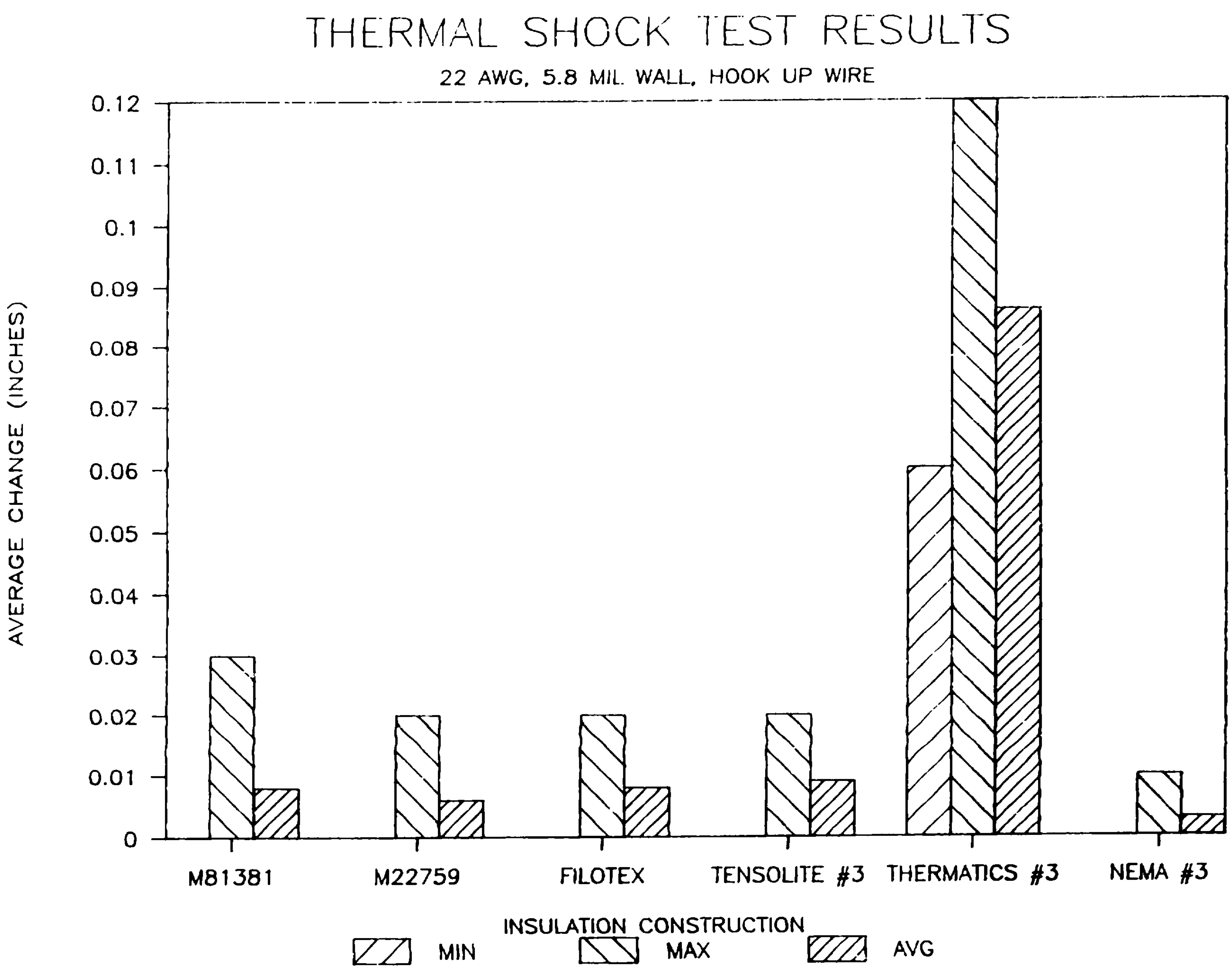

FIGURE 5.101 - THERMAL SHOCK TEST RESULTS, 22AWG, 5.8 MIL WALL HOOK UP WIRE

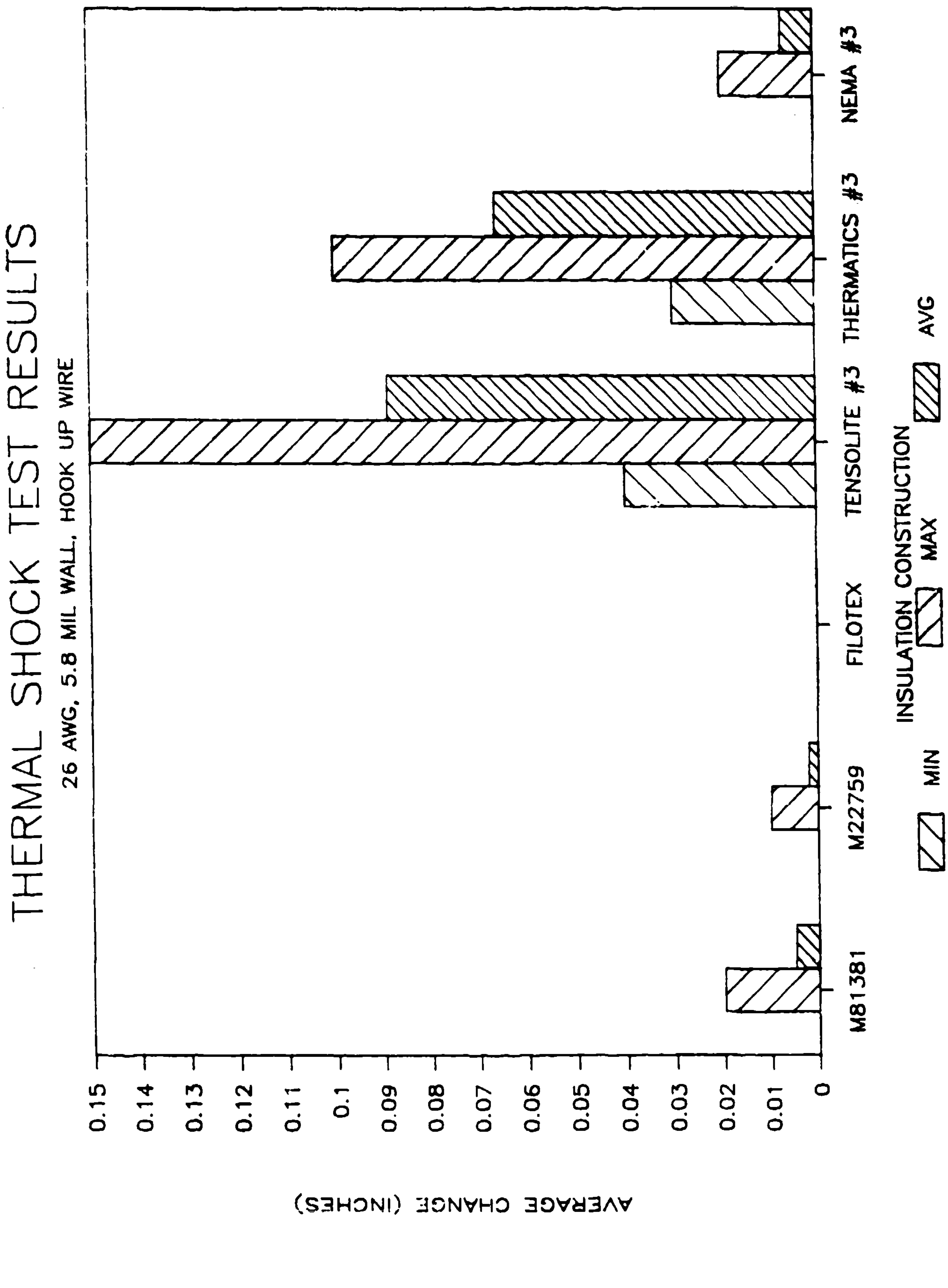

FIGURE 5.102 - THERMAL SHOCK TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

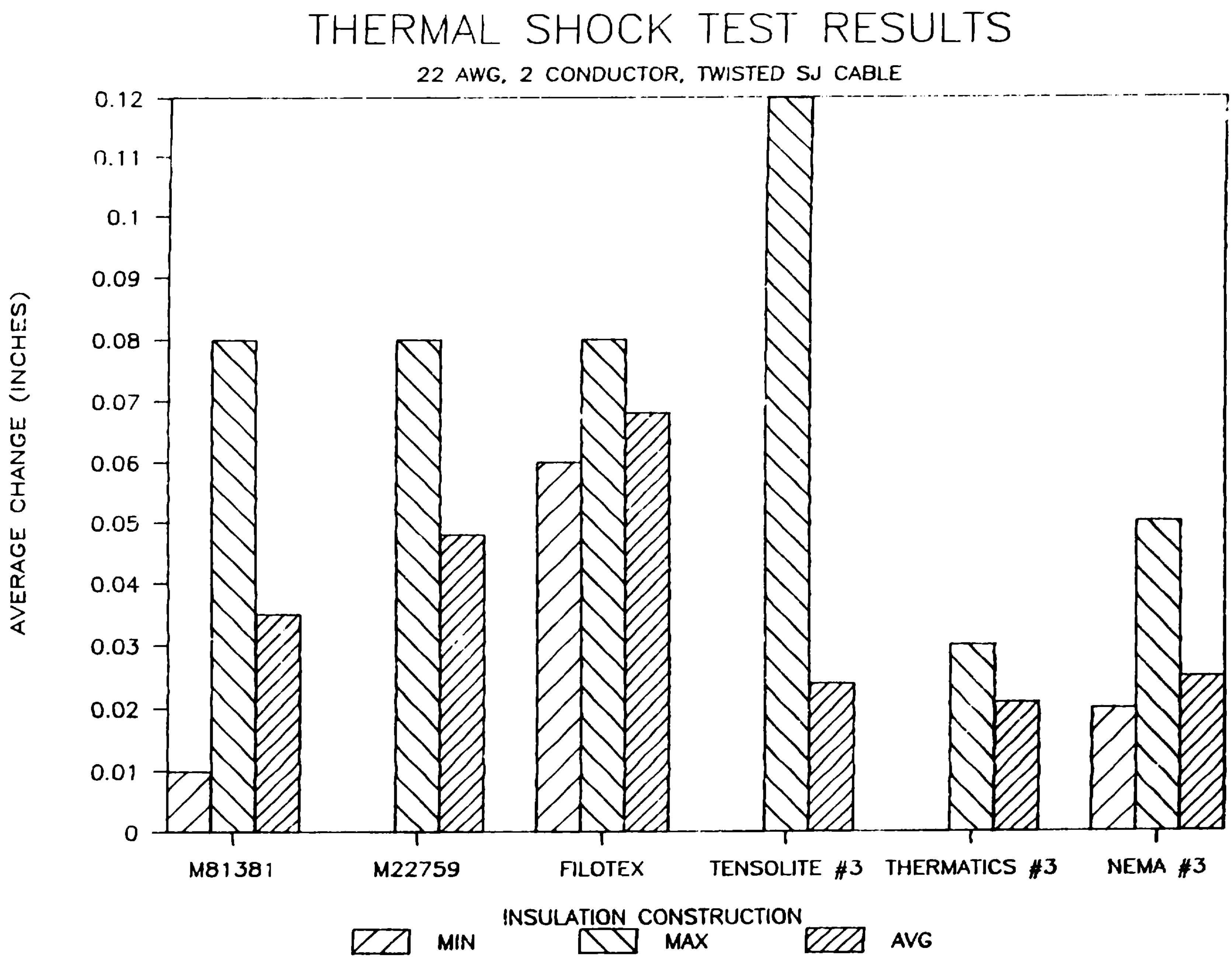

FIGURE 5.103 - THERMAL SHOCK TEST RESULTS, 22AWG, 2 CONDUCTOR, TWISTED SJ CABLE

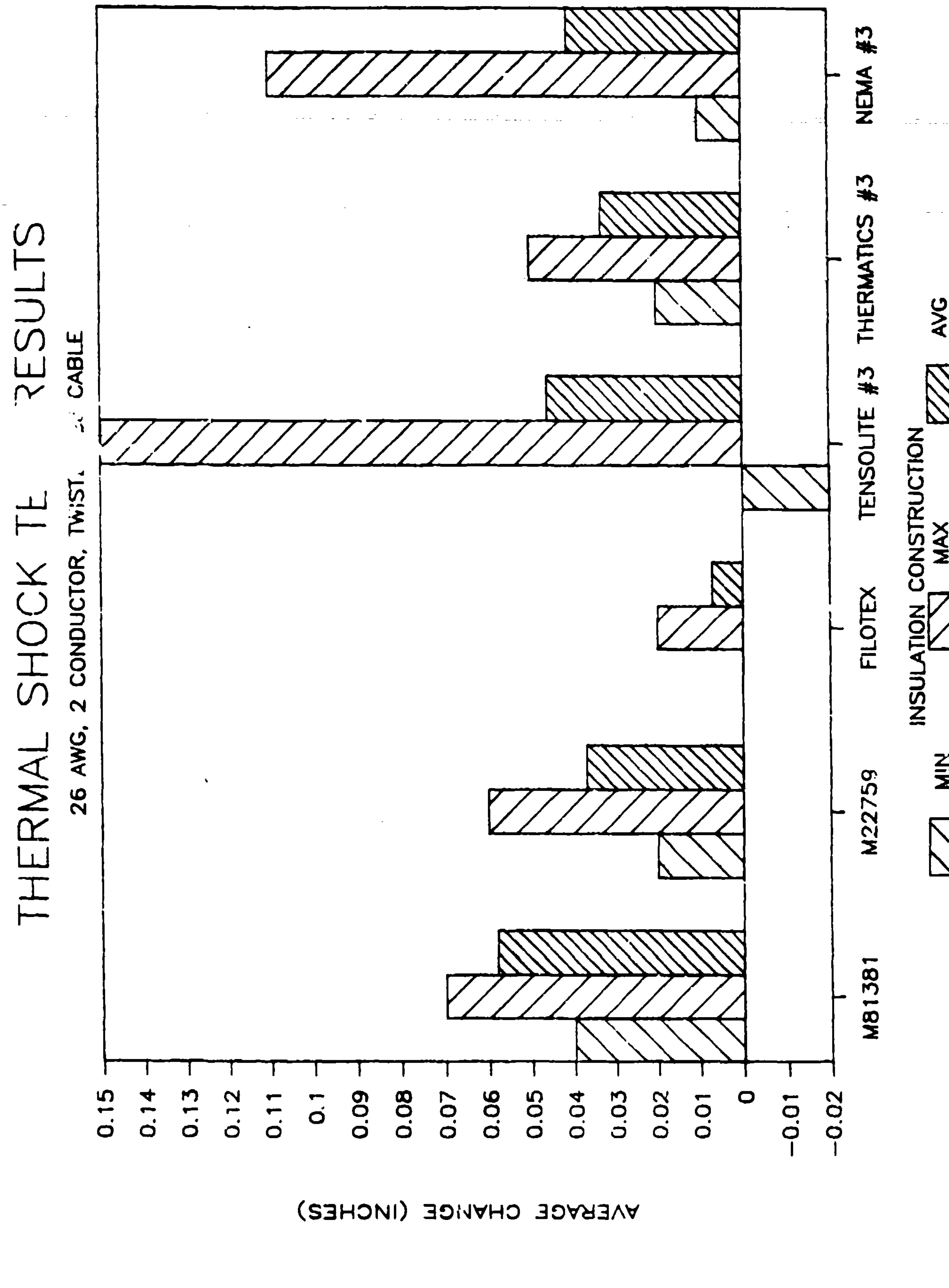

FIGURE 5.104 - THERMAL SHOCK TEST RESULTS, 26AWG, 2 CONDUCTOR, TWISTED SJ CABLE

FIGURE 5.105 - THERMAL SHOCK TEST SETUP

FIGURE 5.106 - THERMAL SHOCK TEST RACK

5.6.5 PROPERTY RETENTION AFTER THERMAL AGING.

5.6.5.1 Scope: The Property Retention after Thermal Aging Test evaluated the ability of a wire's insulation to maintain mechanical properties after thermal aging for 1000 hours at 200°C (392°F).

5.6.5.2 Reference Procedure: The Property Retention after Thermal Aging Test was conducted according to Method 807 of SAE AS4373, with the addition of a Voltage Withstand Test (SAE AS4373, Method 510), an Insulation Resistance Test (SAE AS4373, Method 504), and an Examine Product Test (SAE AS4372, Paragraph 3.1.4).

5.6.5.3 Specimens: Specimens were constructed from 22 gauge, 8.6 mil wall, airframe wire; 22 gauge, 5.8 mil wall, hook up wire; and 26 gauge, 5.8 mil wall, hook up wire. One-hundred and twenty feet of each sample was cut and coiled into 8 inch diameter coils. The coils were loosely tied with fiberglass (MIL-T-43435B, type IV) lacing tape to retain the shape of a coil.

5.6.5.4 Test equipment: A Blue M oven (MD 106637) with a Touch Master Control and vented to the outside was used for the thermal aging.

5.6.5.5 Test Procedure: The specimens were placed sparsely in the chamber on metal racks for 1000 hours at 200°C. At completion of the thermal aging, the specimens were subjected to the following tests:

Abrasion (SAE AS4373, Method 701)
Dynamic Cut Through (SAE AS4373, Method 703)
Flex Life (SAE AS4373, Method 704)
Notch Propagation (SAE AS4373, Method 707)
Voltage Withstand (SAE AS4373, Method 510)
Insulation Resistance (SAE AS4373, Method 504)
Examine Product (SAE AS4372, Paragraph 3.1.4)

5.6.5.6 Test Results: The individual test results are presented under their respective sections within the screening and full performance test sections. The screening test section includes the test results on the thermally aged specimens while the full performance test section includes the results on the unconditioned specimens. The test results average percentage change between the unconditioned specimens and the thermally aged specimens are presented in Tables 5.101 through 5.103 with a graphical representation of the data presented in Figures 5.107 through 5.109.

TABLE 5.101 - PROPERTY RETENTION AFTER THERMAL AGING TEST RESULTS ON 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

SPOOL REF.	INSULATION CONSTRUCTION	PERCENTAGE CHANGE ABRASION	DYNAMIC CUT THROUGH	FLEX LIFE	NOTCH PROP.	AVERAGE
101	M81381	-72	-4	-71	0	-37
106	M22759	+67	-9	-67	0	-2
136	FILOTEX	+32	+42	-14	0	+15
141	TENSOLITE #3	-43	+49	-54	0	-12
146	THERMATICS #3	-27	-4	+195	0	+43
156	NEMA #3	-21	+17	-65	0	-17

TABLE 5.102 - PROPERTY RETENTION AFTER THERMAL AGING TEST RESULTS ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	PERCENTAGE CHANGE ABRASION	DYNAMIC CUT THROUGH	FLEX LIFE	NOTCH PROP.	AVERAGE
102	M81381	-56	-1	-56	0	-28
107	M22759	+51	+11	-23	-15	+6
137	FILOTEX	+34	+11	-3	0	+11
142	TENSOLITE #3	-45	+48	-38	0	-9
147	THERMATICS #3	+11	+18	+66	0	+24
157	NEMA #3	+1	+17	-51	0	-8

TABLE 5.103 - PROPERTY RETENTION AFTER THERMAL AGING TEST RESULTS ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	PERCENTAGE CHANGE DYNAMIC CUT THROUGH	FLEX LIFE	NOTCH PROP.	AVERAGE
103	M81381	-9	-75	0	-28
108	M22759	-28	-57	-68	-51
138	FILOTEX	-16	-10	0	-9
143	TENSOLITE #3	+18	+36	0	+18
148	THERMATICS #3	+1	+39	0	+13
158	NEMA #3	+35	-46	0	-4

-% = Performance was reduced on thermally aged specimens
+% = Performance was increased on thermally aged specimens

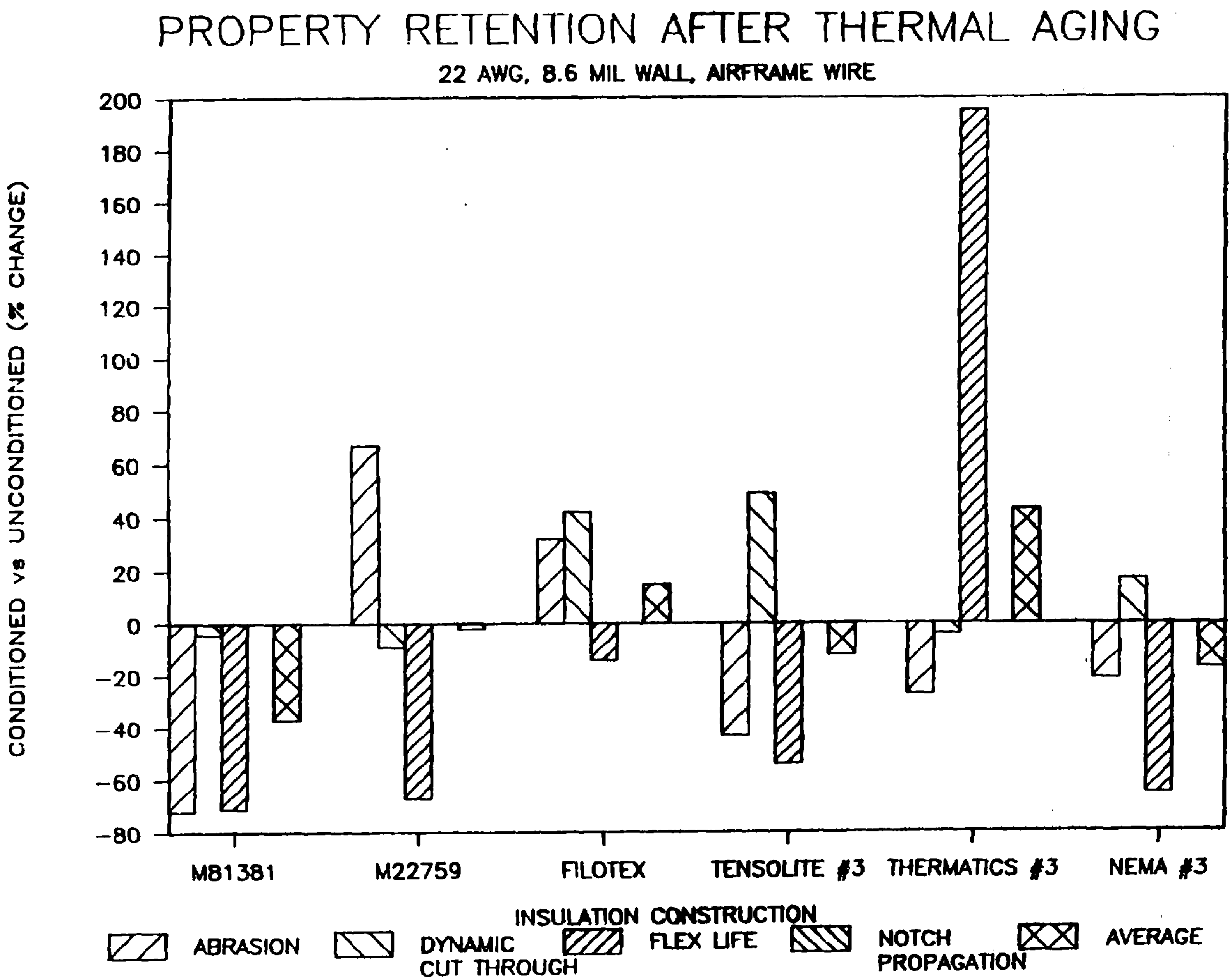

FIGURE 5.107 - PROPERTY RETENTION AFTER THERMAL AGING, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

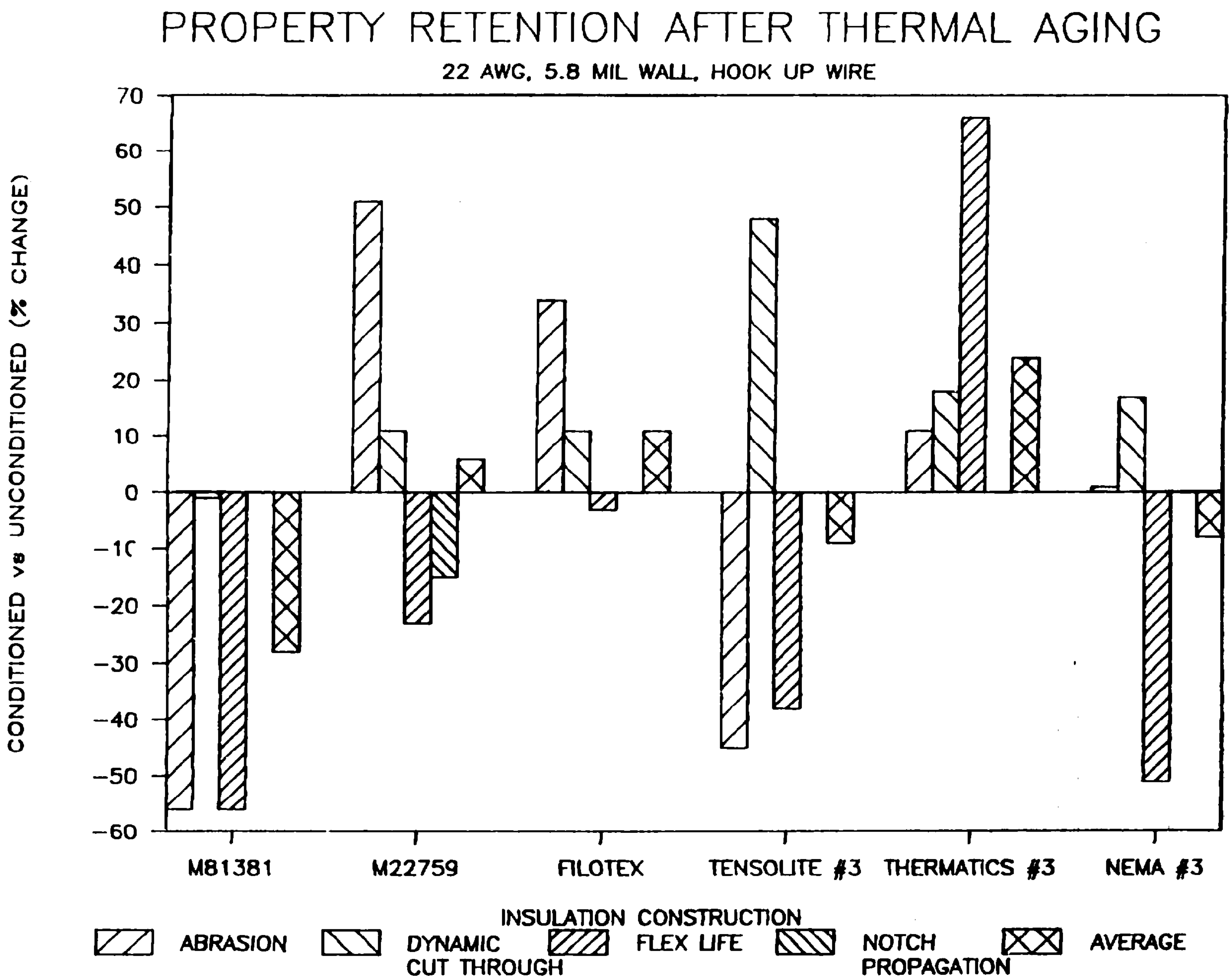

FIGURE 5.108 - PROPERTY RETENTION AFTER THERMAL AGING, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

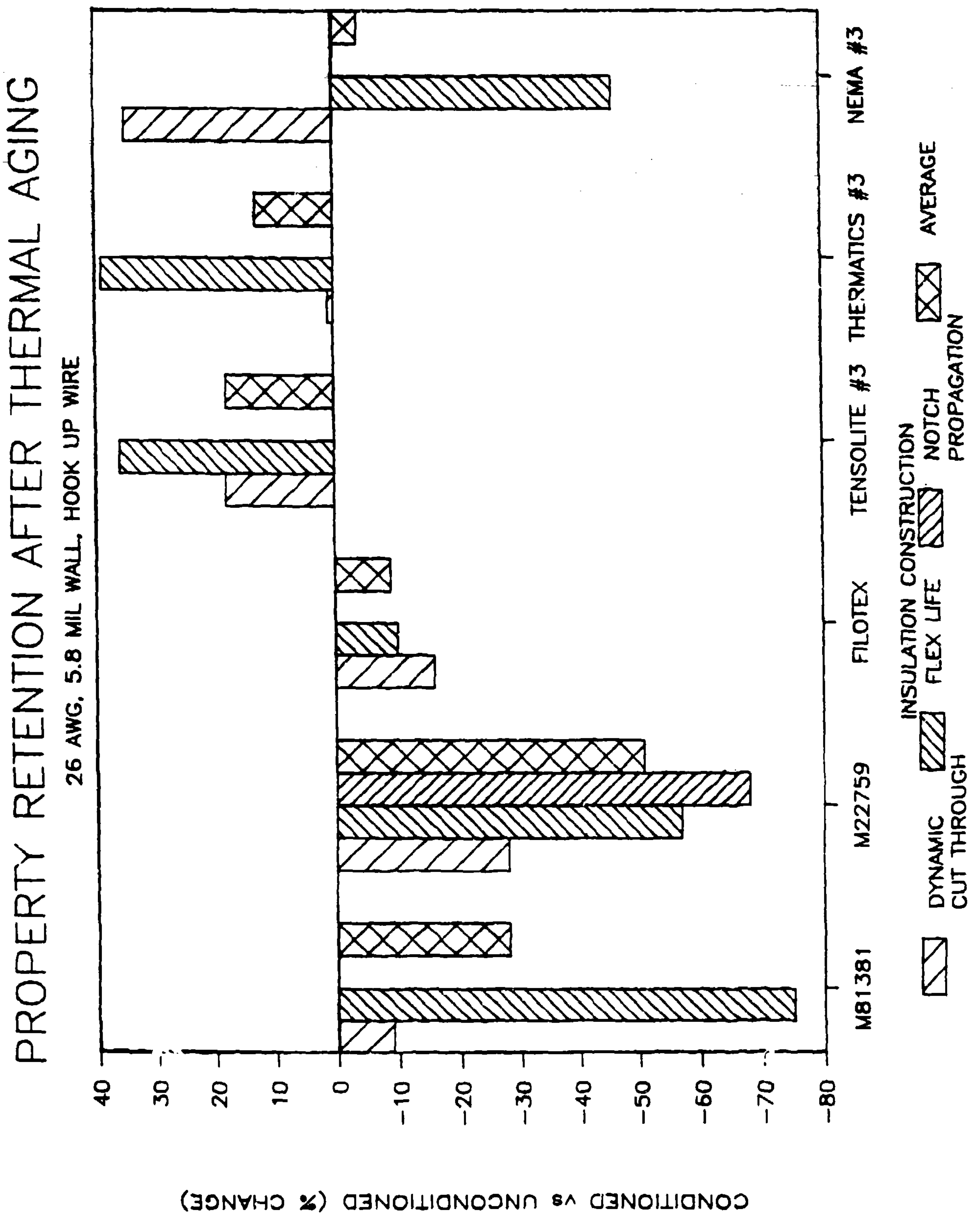

FIGURE 5.109 - PROPERTY RETENTION AFTER THERMAL AGING, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

5.7 MARKING AND PACKAGING TESTS

5.7.1 WIRE SURFACE MARKABILITY.

5.7.1.1 Scope: The Wire Surface Markability Test was used to determine the ability of a finished wire insulation to receive and maintain the quality of different types of wire marking after exposure to various environments.

5.7.1.2 Reference Procedure: The Wire Surface Markability Test was performed by Douglas Aircraft Company (DAC). Since Method 713 of SAE AS4373 was not defined, the Wire Surface Markability Test was conducted according to Douglas Material Specification 2325, Paragraph 4.1.5, Types 2 and 3. The specimens were marked with three types of wire marking systems; Hot Stamp, Excimer Laser, and Ink Jet. The specimens were segmented and subjected to a Fluid Immersion Test and an Abrasion Durability Test.

5.7.1.3 Specimens: Specimens were prepared for 22 and 26 gauge, 5.8 mil wall, hook up wire. Three, 12 foot specimens of each sample were marked, one specimen with a hot stamp mark, one specimen with an excimer laser mark, and one specimen with an ink jet mark. There was one exception, the 26 gauge specimens were not marked with the hot stamp marking machine. The 12 foot specimens

were then cut into four three foot specimens, one specimen for each of the fluids tested. Each of the three foot specimens had a minimum of six separate marks. The specimens were marked with the letters "TEST 1234ABCD."

The excimer laser marks on the 22 and 26 gauge, 5.8 mil wall, M81381 hook up wire specimens were not visible to the naked eye and therefore not tested. The polyimide topcoat on M81381 wire is known to have poor excimer laser mark capability.

5.7.1.4 Test Equipment: A 2.5 pound weight and abrasive felt per Douglas Manufacturing Specification 2059, Type 1, Class 16R1X, was used to conduct the Abrasion Durability Test.

The Excimer Laser Mark was placed on the specimens by a Caris 500 Cable Printing and Identification System, courtesy of Spectrum Technologies.

The Hot Stamp Mark was placed on the specimens by Douglas Aircraft using a Conrac Hot Stamp Marking Process according to Douglas Manufacturing Specification 2118.

The Ink Jet Mark was placed on the specimens by Douglas Aircraft using a Am-Jet 500 Domino Wire Marker.

5.7.1.5 Test Procedure: One specimen was soaked for one minute in each of the following chemicals at room temperature: MIL-H-83282 Hydraulic Fluid, Skydrol 500 LD

Hydraulic Fluid, MIL-L-23699 Lubricating Oil, and MIL-T-5624 Jet Fuel (JP-4). After immersion, the specimens were blotted dry with a clean, dry paper towel. The specimens were examined for legibility with the naked eye at a distance of 14 inches minimum in ambient light. If any portion of any character of the six marks on the specimen was not continuous, the specimen was labeled a failure.

An Abrasion Durability Test was conducted according to Douglas Manufacturing Specification 2059, Type 1, using a Class 16R1X abrasive felt pad, attached to a 2.5 pound weight, to rub each mark 20 times (10 cycles) at a rate of 2 to 3 cycles per second. After 20 rubs, each specimen was examined for continuity and legibility with the naked eye at a distance of 14 inches minimum in ambient light. The specimen was labeled a failure if any portion of any character was completely rubbed through on any of the six marks on the specimen.

5.7.1.6 Test Results: The test results of the Wire Surface Markability Tests are presented in Tables 5.104 through 5.108.

TABLE 5.104 - WIRE MARKABILITY TEST RESULTS USING HOT STAMP MARK ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MARK MACHINE	CHEMICAL-ABRASION TEST (PASS/FAIL) SKYDROL	MIL-H-83282	MIL-L-23699	JP-4
202	M81381	CONRAC	F	F	F	F
207	M22759	CONRAC	P	P	P	P
237	FILOTEX	CONRAC	F	P	P	P
242	TENSOLITE #3	CONRAC	F	P	P	P
247	THERMATICS #3	CONRAC	P	P	P	P
257	NEMA #3	CONRAC	P	P	P	P

TABLE 5.105 - WIRE MARKABILITY TEST RESULTS USING EXCIMER LASER MARK ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MARK MACHINE	CHEMICAL-ABRASION TEST (PASS/FAIL) SKYDROL	MIL-H-83282	MIL-L-23699	JP-4
202	M81381	LASER	VIS	VIS	VIS	VIS
207	M22759	LASER	P	P	P	P
237	FILOTEX	LASER	P	P	P	P
242	TENSOLITE #3	LASER	F	P	F	P
247	THERMATICS #3	LASER	ILL	ILL	ILL	ILL
257	NEMA #3	LASER	P	P	P	P

TABLE 5.106 - WIRE MARKABILITY TEST RESULTS USING EXCIMER LASER MARK ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MARK MACHINE	CHEMICAL-ABRASION TEST (PASS/FAIL) SKYDROL	MIL-H-83282	MIL-L-23699	JP-4
203	M81381	LASER	VIS	VIS	VIS	VIS
208	M22759	LASER	P	P	P	P
238	FILOTEX	LASER	P	P	P	P
243	TENSOLITE #3	LASER	F	F	F	F
248	THERMATICS #3	LASER	P	P	P	P
258	NEMA #3	LASER	ILL	ILL	ILL	ILL

VIS = MARK WAS NOT VISIBLE TO NAKED EYE.
ILL = MARK WAS ILLEGIBLE.

TABLE 5.107 - WIRE MARKABILITY TEST RESULTS USING INKJET MARK ON 22 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MARK MACHINE	CHEMICAL-ABRASION TEST (PASS/FAIL) SKYDROL	MIL-H-83282	MIL-L-23699	JP-4
202	M81381	INKJET	P	P	P	P
207	M22759	INKJET	P	P	P	F
237	FILOTEX	INKJET	F	F	F	F
242	TENSOLITE #3	INKJET	F	F	F	F
247	THERMATICS #3	INKJET	N/A	N/A	N/A	N/A
257	NEMA #3	INKJET	F	F	F	F

TABLE 5.108 - WIRE MARKABILITY TEST RESULTS USING INKJET MARK ON 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

SPOOL REF.	INSULATION CONSTRUCTION	MARK MACHINE	CHEMICAL-ABRASION TEST (PASS/FAIL) SKYDROL	MIL-H-83282	MIL-L-23699	JP-4
203	M81381	INKJET	P	P	P	P
208	M22759	INKJET	F	F	F	F
238	FILOTEX	INKJET	ILL	ILL	ILL	ILL
243	TENSOLITE #3	INKJET	ILL	ILL	ILL	ILL
248	THERMATICS #3	INKJET	ILL	ILL	ILL	ILL
258	NEMA #3	INKJET	P	P	P	P

ILL = MARK WAS ILLEGIBLE.
N/A = SPECIMENS WERE NOT AVAILABLE.

6.0 FINAL STATISTICAL ANALYSIS

6.1 METHODS OF ANALYSIS. In order to discuss test results objectively, it was necessary to translate the raw data into meaningful values for comparison. Two different statistical approaches were taken to analyze the test data and each is discussed below.

The first method utilizes the unbiased standard deviation to determine a relative ranking in performance for the final four candidates and two baselines. When using this method, a score of 0.0 is the best possible score. All other scores are based on each construction's deviation from the best possible score. This method is described in detail in section 4.1 and is reflected in Tables 6.1 through 6.6 for overall (Screening and Full Performance) tests.

The second method is described in the Naval Avionics Center's TR-2333. This method uses the Analysis of Variance (AOV) test to determine if differences exist between data values and then uses the Student-Newman-Keuls (SNK) test to determine if the differences are significant. The SNK method groups data by assigning symbols to each sample tested. Samples with like symbols cannot be statistically differentiated in performance, even though the raw data may show some difference in numerical values. Samples which have differing symbols are said to have statistically different performance levels. This method is reflected

in Tables 6.7 through 6.40, where the tests are separated according to categories.

6.2 SUMMARIES OF TEST DATA. Method 1 standard deviation analysis will be used to present summary data of screening and full performance test results for the four final candidates and two baselines. Screening data is repeated from section 4, and Full Performance data is newly calculated. The two have been combined in the tables without distinction, with the exception of the retained properties tests which were performed in both test sections (thermally aged specimens were tested in Screening and unaged specimens were tested in Full Performance).

6.2.1 UNWEIGHTED OVERALL STATISTICAL RESULTS. An overall summary of the unweighted statistical results is shown in Table 6.1. All individual test statistical performances are shown in the columns beneath the respective test name and the bottom far right column shows the overall average score for each construction. Where multiple gauges and/or wall thicknesses were tested, 22 gauge airframe, 22 gauge hookup wire, and 26 hookup wire test results were all combined to give a single test score for each construction. We chose not to include the shielded and jacketed performance statistics in the overall summary results because the jackets were not specified for the

test program. As previously noted, the lowest score indicates the highest performance. The table is arranged to list the best performer at the top moving sequentially down to the worst performer at the bottom.

Tensolite is the top performer in the unweighted overall summary, followed by Filotex, the baseline M81381, and the fourth place candidate, Thermatics. NEMA #3 follows Thermatics and M22759 is sixth.

6.2.2 WEIGHTED OVERALL STATISTICAL RESULTS. As described in paragraph 4.2.2, each test was given a specific weight value according to the determined importance of the test. The assigned weights are listed individually beneath each test heading and as a sum at the bottom of the table. The average score is determined by adding all of the individual test scores and dividing by the sum of the weights given to the tests. The weighted overall results for both the screening and full performance tests are shown in Table 6.2.

The ranking of the top three performers differs between the weighted and unweighted summaries. In the weighted overall results, Filotex has moved from second place into first place, followed by Tensolite, with M81381 remaining in third place. The bottom three performers remained in the same ranking. Filotex and Tensolite are statistically ranked very closely, with

M81381 and Thermatics somewhat close behind. The largest statistical jump is seen between Thermatics and NEMA #3, with another medium change between NEMA #3 and M22759.

6.2.3 22 GAUGE AIRFRAME WIRE OVERALL SUMMARY. Statistical results for the tests run on 22 gauge airframe wire are shown in Table 6.3. Ranking varied slightly between the 22 gauge airframe summary and the overall summary. M81381 moved to first place, followed by Filotex and Thermatics in a very close third. Tensolite dropped to fourth and NEMA #3 and M22759 remained in fifth and sixth places.

6.2.4 22 GAUGE HOOK UP WIRE OVERALL SUMMARY. Statistical results for the tests run on 22 gauge hook up wire are shown in Table 6.4. Again ranking varied slightly from the overall summary. Tensolite and Filotex exchanged first and second places, M81381 remained in third, NEMA #3 and Thermatics exchanged fourth and fifth places and M22759 remained in sixth.

6.2.5 26 GAUGE HOOK UP WIRE OVERALL SUMMARY. Statistical results for the tests run on 26 gauge hook up wire are shown in Table 6.5. Ranking varied from the overall summary. M81381 moved to first place, as it had in the 22 gauge airframe summary. A large statistical change was seen before reaching Filotex in second place.

Tensolite and NEMA #3 followed closely behind Filotex. Thermatics placed fifth and a large statistical variance kept M22759 in sixth place.

6.2.6 **SHIELDED AND JACKETED CABLE OVERALL SUMMARY.** Statistical results for the tests run on 22 gauge and 26 gauge, two conductor shielded and jacketed cable are shown in Table 6.6. Shielded and jacketed results are summarized even though they are not included as part of the overall statistical summary. An average score is not presented for Filotex because samples were not available during the Screening Tests, making Filotex results incomplete. Tensolite, with an extruded PFA jacket, was the best performer by a significant statistical margin.

6.3 **CATEGORICAL RESULTS.** The data will now be categorized by test and reviewed for relative performance in each category by analysis Method 1. Individual tests for each category will also be reviewed using the SNK analysis described by Method 2, using numbers as the separating symbols. In reviewing the SNK results, remember that only the samples with no symbols in common are truly statistically separable and that, in these analyses, the smaller the number is, the better that candidate performed. The test categories are listed below:

GENERAL
COMBAT DAMAGE
ELECTRICAL
ENVIRONMENTAL
MARKING
MECHANICAL
THERMAL
WEIGHT AND DIMENSIONAL

6.3.1 **GENERAL.** The Test Result Summary on General Tests is shown in Table 6.7. Filotex and Thermatics were the top performers, followed by M22759 and Tensolite in close ranking, with a large variance between the next two candidates, M81381 and NEMA #3.

The results of SNK analyses on the Examine Product test are shown in Table 6.8. There was not enough statistical variation in Workmanship to get an accurate separation in the SNK test, so the information is not presented.

TABLE 6.7 - TEST RESULTS SUMMARY - GENERAL

INSULATION CONSTRUCTION	WORKMANSHIP	EXAMINE PRODUCT	AVERAGE SCORE (X10)
FILOTEX	0.00	0.75	1.25
THERMATICS	2.03	1.59	6.03
TENSOLITE	4.06	2.31	10.62
M22759	3.54	3.09	11.05
M81381	3.29	5.46	14.58
NEMA #3	3.54	6.93	17.45

SUM WEIGHT = 6.0

TABLE 6.8 SNK ON EXAMINE PRODUCT

FILOTEX	1	Best Product
THERMATICS	1	
TENSOLITE	1	
M22759	1	
M81381	2	
NEMA #3	2	Worst Product

The following statements can be made about the Examine Product test results:

There is no discernible difference in products between the Filotex, Thermatics, Tensolite, and M22759.

There is no discernible difference in products between the M81381 and NEMA #3.

Filotex, Thermatics, Tensolite, and M22759 had fewer anomalies than M81381 and NEMA #3 insulation.

6.3.2 COMBAT DAMAGE. The Test Result Summary on Combat Damage Tests is shown in Table 6.9. Tensolite is the best performer and M81381 is the worst performer through a great statistical variance. M22759, Thermatics, and Filotex all were ranked in close order, with a larger variation separating NEMA #3 from Filotex.

The results of SNK analyses on individual tests are shown in Tables 6.10 and 6.11.

TABLE 6.9 - TEST RESULTS SUMMARY - COMBAT DAMAGE

INSULATION CONSTRUCTION	DRY ARC RESISTANCE	BSI DRY ARC RESISTANCE	AVERAGE SCORE (X10)
TENSOLITE	0.06	0.11	0.15
M22759	4.68	0.06	4.31
THERMATICS	4.90	0.06	4.51
FILOTEX	5.12	0.00	4.65
NEMA #3	1.92	9.62	10.49
M81381	15.18	19.47	31.50

SUM WEIGHT = 11

TABLE 6.10 - SNK ON DRY ARC RESISTANCE
(115 VAC / 28 VDC, SPLAYED ENDS)

FILOTEX	1	Least evidence of propagation
NEMA #3	1	
TENSOLITE	1	
THERMATICS	1	
M22759	1	
M81381	2	Most evidence of propagation

The following statements can be made about the Dry Arc Resistance Test results:

No discernible difference in products between the Filotex, NEMA #3, Tensolite, Thermatics, and M22759.

M81381 is more susceptible to arc propagation than the other five constructions.

TABLE 6.11 - SNK ON BRITISH STANDARDS INSTITUTE (BSI) DRY ARC RESISTANCE AND FAULT PROPAGATION TEST

FILOTEX	1	Shortest average current duration
TENSOLITE	1	
THERMATICS	1	
M22759	1	
NEMA #3	2	
M81381	3	Longest average current duration

The following statements can be made about the BSI Dry Arc Resistance and Fault Propagation Test results:

No discernible difference in products can be made between Filotex, Tensolite, Thermatics, and M22759.

Filotex, Tensolite, Thermatics, and M22759 sustain arc current for a shorter amount of time than NEMA #3 and M81381.

NEMA #3 sustains arc current for a shorter amount of time than M81381.

6.3.3 ELECTRICAL. The Test Result Summary on Electrical Tests is shown in Table 6.12. Tensolite is the outstanding performer followed by Filotex, Thermatics, M81381, NEMA #3, and M22759 in a close grouping.

The results of SNK analyses on individual tests are shown in Tables 6.13 through 6.17. All candidates performed equally well in the Voltage Withstand,

Insulation Resistance, and Surface Resistance Tests so that an SNK analysis is not necessary on these tests and therefore not presented.

TABLE 6.12 - TEST RESULTS SUMMARY - ELECTRICAL

INSULATION CONSTRUCTION	VOLTAGE WITHSTAND	INSULATION RESISTANCE	DIELECTRIC CONSTANT	AC CORONA	SURFACE RESISTANCE
TENSOLITE	0.00	0.00	0.00	0.00	0.00
FILOTEX	0.00	0.00	2.44	2.74	0.00
THERMATICS	0.00	0.00	4.52	8.61	0.00
M81381	0.00	0.00	4.82	5.18	0.00
NEMA #3	0.00	0.00	2.28	3.96	0.00
M22759	0.00	0.00	1.62	3.43	0.00

TABLE 6.12 - TEST RESULTS SUMMARY - ELECTRICAL (CONT.)

INSULATION CONSTRUCTION	TIME / CURRENT TO SMOKE	WET ARC TRACK	WIRE FUSING TIME	AVG SCORE (X10)
TENSOLITE	0.36	0.13	1.92	0.89
FILOTEX	4.03	0.38	7.68	6.35
THERMATICS	0.30	0.10	5.79	7.10
M81381	3.27	5.38	1.28	7.33
NEMA #3	6.86	1.02	7.33	7.89
M22759	5.51	3.39	8.32	8.19

SUM WEIGHT = 27.2

TABLE 6.13 - SNK ON DIELECTRIC CONSTANT DATA

TENSOLITE	1		Lowest dielectric constant
M22759	1		
NEMA #3	1	2	
FILOTEX	1	2	
THERMATICS		2	
M81381		2	Highest dielectric constant

The following statements can be made about the Dielectric Constant Test results:

No discernible difference in products can be made between Tensolite, M22759, NEMA #3, and Filotex.

No discernible difference in products can be made between NEMA #3, Filotex, Thermatics, and M81381.

Tensolite and M22759 have a lower dielectric constant than Thermatics and M81381.

TABLE 6.14 - SNK ON AC CORONA DATA

TENSOLITE	1	Highest average inception voltage
FILOTEX	2	
NEMA #3	2	
M22759	2	
M81381	2	
THERMATICS	3	Lowest average inception voltage

The following statements can be made about the AC Corona Test results:

Tensolite has the highest average inception voltage.

No discernible difference in products can be made between Filotex, NEMA #3, M22759, and M81381. These constructions have a lower average inception voltage than Tensolite, and a higher average inception voltage than Thermatics.

Thermatics has the lowest average inception voltage.

TABLE 6.15 - SNK ON TIME/CURRENT TO SMOKE DATA

THERMATICS	1		Highest current for the longest time
FILOTEX	1	2	
TENSOLITE	1	2	
M22759	1	2	
M81381	1	2	
NEMA #3		2	Lowest current for the shortest time

Note: The worst case performer for each construction was used to determine statistical ranking.

The following statements can be made about the Time/Current to Smoke test results:

No discernible difference in products can be made between Thermatics, Filotex, Tensolite, M22759, and M81381.

No discernible difference in products can be made between

Filotex, Tensolite, M22759,
M81381, and NEMA #3.

The only discernible difference is between Thermatics and NEMA #3, with Thermatics being able to pass higher current for a longer amount of time than NEMA #3.

TABLE 6.16 SNK ON WET ARC TRACK DATA

FILOTEX	1	Least evidence of tracking
NEMA #3	1	
TENSOLITE	1	
THERMATICS	1	
M22759	2	
M81381	3	Most evidence of tracking

The following statements can be made about the Wet Arc Track Test results:

No discernible difference in products can be made between Filotex, NEMA #3, Tensolite, and Thermatics candidates. These candidates showed less evidence of arc tracking than either M22759 or M81381.

M22759 showed less evidence of arc tracking than M81381.

TABLE 6.17 SNK ON WIRE FUSING TIME DATA

TENSOLITE	1	Longest average time to fuse
M81381	1	
FILOTEX	2	
NEMA #3	2	
THERMATICS	2	
M22759	2	Shortest average time to fuse

The following statements can be made about the Wire Fusing Time test results:

No discernible difference in products can be made between Tensolite and M81381.

No discernible difference in products can be made between Filotex, NEMA #3, Thermatics, and M22759.

Tensolite and M81381 do not fuse as quickly as Filotex, NEMA #3, Thermatics, and M22759.

6.3.4 **ENVIRONMENTAL.** The Test Result Summary of the Environmental Tests is shown in Table 6.18. M22759 and Tensolite are the first and second best performers, followed by NEMA #3, Filotex, Thermatics, and M81381. The results of the SNK analyses on individual tests are shown in Tables 6.19 through 6.20. There was not enough statistical variation in the Fluid Immersion, Weight

Loss/Outgassing, and Weathering Resistance Tests to get an accurate separation in the SNK test, so that information is not presented. All constructions performed equally well in the Wicking Test and SNK analysis is not presented.

TABLE 6.18 - TEST RESULTS SUMMARY - ENVIRONMENTAL

INSULATION CONSTRUCTION	FLUID IMMER.	FORCED HYDROL.	HUMIDITY RESIST.	WT LOSS OUTGASS	WEATHER RESIST.	WICK	AVG SCORE (X10)
M22759	0.22	0.00	0.00	5.19	1.26	0.00	3.07
TENSOLITE	0.58	0.00	7.38	0.64	0.00	0.00	3.96
NEMA #3	0.32	0.00	9.45	3.70	0.00	0.00	6.21
FILOTEX	1.04	4.38	7.42	2.82	0.00	0.00	7.22
THERMATICS	0.45	3.85	11.74	1.58	0.56	0.00	8.38
M81381	0.72	3.43	11.92	3.30	0.00	0.00	8.93

SUM WEIGHT = 21.7

TABLE 6.19 SNK ON FORCED HYDROLYSIS DATA

NEMA #3	1	Least leakage current with fewest failures
TENSOLITE	1	
M22759	1	
FILOTEX	2	
THERMATICS	2	
M81381	2	Highest leakage current with most failures

The following statements can be made about the Forced Hydrolysis test results:

No discernible difference in products can be made between NEMA #3, Tensolite, and M22759.

No discernible difference in products can be made between

Filotex, Thermatics, and M81381.

NEMA #3, Tensolite, and M22759 have a lower leakage current with fewer failures than Filotex, Thermatics, and M81381.

TABLE 6.20 - SNK ON HUMIDITY RESISTANCE DATA

M22759	1	Highest calculated insulation resistance
FILOTEX	2	
NEMA #3	2	
TENSOLITE	2	
THERMATICS	3	
M81381	3	Lowest calculated insulation resistance

The following statements can be made about the Humidity Resistance Test results:

No discernible difference in products can be made between Filotex, NEMA #3, and Tensolite.

No discernible difference in products can be made between Thermatics and M81381.

M22759 has the highest calculated insulation resistance.

Filotex, NEMA #3, and Tensolite have a higher calculated

insulation resistance than Thermatics and M81381.

6.3.5 MARKING. The Test Result Summary on Marking Tests is shown in Table 6.21. Wire surface markability is the only test contained in this category. The results show that M22759 marked the best, followed by NEMA #3, Filotex, Tensolite, Thermatics, and M81381 in last place. The results of the SNK are not presented because there was not enough statistical variation to break the constructions into more than one group.

TABLE 6.21 - TEST RESULTS SUMMARY - MARKING

INSULATION CONSTRUCTION	WIRE SURFACE MARKABILITY
M22759	0.68
TENSOLITE	2.77
NEMA #3	3.57
FILOTEX	4.86
THERMATICS	5.32
M81381	5.85

SUM WEIGHT = 3.8

6.3.6 MECHANICAL. The Test Result Summary on Mechanical Tests is shown in Table 6.22. M81381 is the best performer, followed at a distance by Tensolite, Thermatics, Filotex, NEMA #3, and M22759. The results of the SNK analyses on individual tests are shown in Tables 6.23 through 6.32.

TABLE 6.22 - TEST RESULTS SUMMARY - MECHANICAL

INSULATION CONSTRUCTION	ABR. (S)	ABR. (F)	DYNAMIC CUT THRU (S)	DYNAMIC CUT THRU (F)	FLEX LIFE (S)	FLEX LIFE (F)	NOTCH PROP (S)	NOTCH PROP (F)
M81381	10.86	2.34	0.00	0.00	1.76	0.00	0.00	0.00
TENSOLITE	12.88	8.11	7.20	9.94	12.04	10.76	0.00	0.00
THERMATICS	5.39	4.99	8.28	8.50	10.12	11.66	0.00	0.00
FILOTEX	3.68	7.28	11.02	10.18	13.04	11.56	0.00	0.00
NEMA #3	15.71	12.38	7.06	8.69	6.93	6.91	0.00	0.00
M22759	15.35	13.00	12.96	12.00	14.08	11.28	6.50	0.00

S - SCREENING; THERMALLY AGED SPECIMENS
F - FULL PERFORMANCE; UNAGED SPECIMENS

TABLE 6.22 - TEST RESULTS SUMMARY - MECHANICAL (CONT.)

INSULATION CONSTRUCTION	STIFF & SPRING.	COLD BEND	CRUSH RESIST.	INSUL. IMPACT RESIST.	INSUL. TENSILE STRENGTH	WIRE TO WIRE RUB	AVG SCORE (X10)
M81381	15.12	4.29	0.00	0.00	3.20	0.00	6.04
TENSOLITE	7.48	0.66	5.40	5.55	3.87	0.00	13.49
THERMATICS	7.77	9.77	6.54	7.35	4.35	0.00	13.62
FILOTEX	6.68	0.00	8.16	7.44	6.02	0.00	13.68
NEMA #3	7.73	3.17	3.96	2.39	6.34	5.82	14.00
M22759	3.78	2.05	3.42	5.18	5.38	3.95	17.51

SUM WEIGHT = 62.2

TABLE 6.23 - SNK ON ABRASION (SCREENING) DATA

FILOTEX	1		Most average cycles to failure
THERMATICS	1		
M81381	2		
TENSOLITE	2	3	
NEMA #3		3	
M22759		3	Least average cycles to failure

The following statements can be made about the Screening Abrasion Test results:

No discernible difference in products can be made between Filotex and Thermatics.

No discernible difference in products can be made between M81381 and Tensolite.

No discernible difference in products can be made between Tensolite, NEMA #3, and M22759.

Filotex and Thermatics are most resistant to abrasion and can sustain the most average cycles to failure.

M81381 can sustain more average cycles to failure than NEMA #3 and M22759.

TABLE 6.24 - SNK ON ABRASION (FULL PERFORMANCE) DATA

THERMATICS	1		Most average cycles to failure
M81381	1		
FILOTEX	1	2	
TENSOLITE	1	2	
NEMA #3		2	
M22759		2	Least average cycles to failure

The following statements can be made about the Full Performance Abrasion Test results:

No discernible difference in products can be made between Thermatics, M81381, Filotex,

and Tensolite.

No discernible difference in products can be made between Filotex, Tensolite, NEMA #3, and M22759.

Thermatics and M81381 were able to sustain more cycles before failing than NEMA #3 and M22759.

TABLE 6.25 - SNK ON DYNAMIC CUT THROUGH (SCREENING) DATA

M81381	1	Largest average force
NEMA #3	2	
TENSOLITE	2	
THERMATICS	2	
FILOTEX	3	
M22759	3	Lowest average force

The following statements can be made about the Screening Dynamic Cut Through Test results:

No discernible difference in products can be made between NEMA #3, Tensolite, and Thermatics.

No discernible difference in products can be made between Filotex and M22759.

M81381 can withstand the largest cut through force.

NEMA #3, Tensolite and Thermatics can withstand a larger cut through force than Filotex and M22759.

TABLE 6.26 - SNK ON DYNAMIC CUT THROUGH (FULL PERFORMANCE) DATA

M81381	1	Largest average force
FILOTEX	2	
NEMA #3	2	
TENSOLITE	2	
THERMATICS	2	
M22759	2	Lowest average force

The following statements can be made about the Full Performance Dynamic Cut Through Test results:

No discernible difference in products can be made between Filotex, NEMA #3, Tensolite, Thermatics, and M22759.

M81381 can withstand the largest cut through force.

TABLE 6.27 - SNK ON FLEX LIFE (SCREENING) DATA

M81381	1			Most average cycles to failure
NEMA #3		2		
FILOTEX		2	3	
TENSOLITE		2	3	
THERMATICS		2	3	
M22759			3	Least average cycles to failure

The following statements can be made about the Screening Flex Life Test results:

No discernible difference in products can be made between NEMA #3, Filotex, Tensolite, and Thermatics.

No discernible difference in products can be made between Filotex, Tensolite, Thermatics, and M22759.

M81381 can withstand the most cycles before failure.

NEMA #3 can withstand more cycles before failure than M22759.

TABLE 6.28 - SNK ON FLEX LIFE (FULL PERFORMANCE) DATA

M81381	1			Most average cycles to failure
NEMA #3		2		
FILOTEX			3	
TENSOLITE			3	
THERMATICS			3	
M22759			3	Least average cycles to failure

The following statements can be made about the Full Performance Flex Life Test results:

> No discernible difference in products can be made between Filotex, Tensolite, Thermatics, and M22759.
>
> M81381 can withstand the most cycles before failure.
>
> NEMA #3 can withstand more cycles before failure than Filotex, Tensolite, Thermatics, and M22759.

TABLE 6.29 - SNK ON NOTCH PROPAGATION (SCREENING) DATA

FILOTEX	1	Most average cycles
NEMA #3	1	
TENSOLITE	1	
THERMATICS	1	
M81381	1	
M22759	2	Least average cycles

The following statements can be made about the Screening Notch Propagation Test results:

> No discernible difference in products can be made between Filotex, NEMA #3, Tensolite, Thermatics, and M81381; and these constructions can

withstand more cycles before failure than M22759.

TABLE 6.30 - SNK ON COLD BEND DATA

FILOTEX	1	Least leakage current with fewest anomalies
TENSOLITE	1	
M22759	2	
NEMA #3	3	
M81381	4	
THERMATICS	5	Most leakage current with most anomalies

The following statements can be made about the Cold Bend Test results:

No discernible difference in products can be made between Filotex and Tensolite; and these two constructions have less leakage current with fewer anomalies than the other four constructions.

M22759 has less leakage current with fewer anomalies than NEMA #3, M81381, and Thermatics.

NEMA #3 has less leakage current with fewer anomalies than M81381 and Thermatics.

M81381 has less leakage current with fewer anomalies than Thermatics.

TABLE 6.31 - SNK ON CRUSH RESISTANCE DATA

M81381	1	Largest average force to failure
FILOTEX	2	
NEMA #3	2	
TENSOLITE	2	
THERMATICS	2	
M22759	2	Smallest average force to failure

The following statements can be made about the Crush Resistance Test results:

No discernible difference in products can be made between Filotex, NEMA #3, Tensolite, Thermatics, and M22759.

M81381 sustains the largest average crush force before failure.

TABLE 6.32 - SNK ON INSULATION IMPACT RESISTANCE DATA

M81381	1	Highest impact force with least failures
NEMA #3	2	
FILOTEX	3	
TENSOLITE	3	
THERMATICS	3	
M22759	3	Lowest impact force with most failures

The following statements can be made about the Insulation Impact Resistance Test results:

No discernible difference in products can be made between

Filotex, Tensolite, Thermatics, and NEMA #3.

M81381 can withstand the highest impact force with the least failures.

NEMA #3 can withstand a higher impact force with fewer failures than Filotex, Tensolite, Thermatics, and M22759.

6.3.7 **THERMAL.** The Test Result Summary of Thermal Tests is shown in Table 6.33. Filotex was the best performer. Thermatics, Tensolite, M81381 and NEMA #3 followed. M22759 was the worst performer. The results of the SNK analyses on individual tests are shown in Tables 6.34 through 6.38. There was not enough statistical variation in the Toxicity Test to get an accurate separation in the SNK analysis, so that information is not presented.

TABLE 6.33 - TEST RESULTS SUMMARY - THERMAL

INSULATION CONSTRUCTION	FLAM	TOXICITY	SMOKE QUANTITY	THERMAL INDEX	THERMAL SHOCK	VER OF RETAINED PROP.	AVG SCORE (X10)
FILOTEX	0.39	1.25	0.04	2.12	0.16	4.56	3.14
THERMATICS	0.86	2.23	0.00	1.72	8.72	1.70	5.62
TENSOLITE	0.09	7.03	0.22	1.20	3.96	7.10	7.23
NEMA #3	1.87	4.00	3.48	7.00	0.44	8.74	9.42
M81381	0.17	9.00	0.00	3.04	1.04	13.26	9.78
M22759	5.49	3.03	10.71	10.88	0.28	6.49	13.61

SUM WEIGHT = 27.1

TABLE 6.34 - SNK ON FLAMMABILITY DATA

FILOTEX	1	Least flame travel
NEMA #3	1	
TENSOLITE	1	
THERMATICS	1	
M81381	1	
M22759	2	Most flame travel

The following statements can be made about the Flammability Test results:

No discernible difference in products can be made between Filotex, NEMA #3, Tensolite, Thermatics, and M81381; and these constructions have less flame travel than M22759.

TABLE 6.35 - SNK ON SMOKE QUANTITY DATA

FILOTEX	1	Lowest smoke density
TENSOLITE	1	
THERMATICS	1	
M81381	1	
NEMA #3	2	
M22759	3	Highest smoke density

The following statements can be made about the Smoke Quantity Test results:

No discernible difference in products can be made between Filotex, Tensolite, Thermatics, and M81381; and these constructions exhibit the lowest smoke density.

NEMA #3 exhibits a lower smoke density than M22759.

TABLE 6.36 - SNK ON THERMAL INDEX DATA

FILOTEX	1	Most hours to 50% failure @ 280°C
TENSOLITE	1	
THERMATICS	1	
M81381	1	
NEMA #3	2	
M22759	3	Least hours to 50% failure @ 280°C

The following statements can be made about the Thermal Index Test results:

No discernible difference in products can be made between Filotex, Tensolite, Thermatics, and M81381.

Filotex, Tensolite, Thermatics, and M81381 can sustain 280°C for more hours before 50%

failure than NEMA #3 or M22759.

NEMA #3 can sustain 280°C for more hours before 50% failure than M22759.

TABLE 6.37 - SNK ON THERMAL SHOCK DATA

FILOTEX	1	Least change
NEMA #3	1	
TENSOLITE	1	
M22759	1	
M81381	1	
THERMATICS	2	Most change

The following statements can be made about the Thermal Shock Test results:

No discernible difference in products can be made between Filotex, NEMA #3, Tensolite, M22759, and M81381; and these construction have less change due to thermal shock than Thermatics.

TABLE 6.38 - SNK ON VERIFICATION OF RETAINED PROPERTIES DATA

THERMATICS	1		Least negative percent change
FILOTEX	1	2	
NEMA #3	1	2	
TENSOLITE	1	2	
M22759	1	2	
M81381		2	Most negative percent change

The following statements can be made about the Verification of Retained Properties Test results:

No discernible difference in products can be made between Thermatics, Filotex, NEMA #3, Tensolite, and M22759.

No discernible difference in products can be made between Filotex, NEMA #3, Tensolite, M22759, and M81381.

Thermatics exhibited less negative percent change in properties between the unaged and aged specimens than M81381.

6.3.8 **WEIGHT AND DIMENSIONAL.** The Test Result Summary on Weight and Dimensional Tests is shown in Table 6.39. M81381 and Filotex were the first and second best performers. M22759 and NEMA #3 were third and fourth place performers. Thermatics was the fifth place performer and a statistical gap separated Tensolite, the worst performer. The results of the SNK analyses on individual tests are listed below. There was not enough statistical variation in the Finished Diameter Test to

get an accurate separation in the SNK analysis, so that information is not presented.

TABLE 6.39 - TEST RESULTS SUMMARY - WEIGHT AND DIAMETER

INSULATION CONSTRUCTION	FINISHED DIAMETER	WIRE WEIGHT	AVG SCORE (X10)
M81381	0.17	1.32	1.77
FILOTEX	0.67	0.97	1.95
NEMA #3	0.00	2.77	3.30
M22759	0.00	3.76	4.48
THERMATICS	0.17	5.64	6.92
TENSOLITE	0.08	11.81	14.15

SUM WEIGHT = 8.4

TABLE 6.40 - SNK ON WIRE WEIGHT DATA

FILOTEX	1	Lowest weight
NEMA #3	1	
M22759	1	
M81381	1	
THERMATICS	2	
TENSOLITE	3	Highest weight

The following statements can be made about the Wire Weight Test results:

No discernible difference in products can be made between Filotex, NEMA #3, M22759, and M81381; and these constructions weighed the least.

Thermatics weighed less than Tensolite.

TABLE 6.2 - OVERALL SUMMARY - WEIGHTED

INSULATION CONSTRUCTION	WORKMAN-SHIP	EXAMINE PRODUCT	DRY ARC RESISTANCE	VOLTAGE WITHSTAND	INSULATION RESISTANCE	FLUID IMMERSION	ABRASION(S)	DYNAMIC CUT THROUGH(S)	FLEX LIFE(S)	NOTCH PROPAGATION(S)	STIFFNESS AND SPRING BACK	FLAMMA-BILITY	TOXICITY	FINISHED DIAMETER	WIRE WEIGHT
WEIGHT FACTOR	3.0	3.0	5.5	5.5	4.5	4.5	5.5	4.5	5.5	5.0	4.2	4.3	5.0	4.2	4.2
Filotex	0	0.75	5.12	0	0	1.04	3.68	11.02	13.04	0	6.68	0.39	1.25	0.67	0.97
Tensolite	4.06	2.31	0.06	0	0	0.58	12.88	7.20	12.04	0	7.48	0.09	7.03	0.08	11.81
M81381	3.29	5.46	15.18	0	0	0.72	10.86	0	1.76	0	15.12	0.17	9.00	0.17	1.32
Thermatics	2.03	1.59	4.90	0	0	0.45	5.39	8.28	10.12	0	7.77	0.86	2.23	0.17	5.64
NEMA #3	3.54	6.93	1.92	0	0	0.32	15.71	7.06	6.93	0	7.73	1.87	4.00	0	2.77
M22759	3.54	3.09	4.68	0	0	0.22	15.35	12.96	14.08	6.50	3.78	5.49	3.03	0	3.76

INSULATION CONSTRUCTION	DIELECTRIC CONSTANT	AC CORONA	SURFACE RESISTANCE	TIME/CURRENT TO SMOKE	WET ARC TRACK	WIRE FUSE TIME	FORCED HYDROLYSIS	HUMIDITY RESISTANCE	WEIGHT LOSS	WEATHERING RESISTANCE	WICKING	WIRE SURF. MARK	ABRASION(FP)	COLD BEND	CRUSH RESIST.
WEIGHT FACTOR	2.0	3.3	2.2	3.3	3.2	3.2	3.5	4.5	2.2	3.5	3.5	3.8	5.2	3.3	3.0
Filotex	2.44	2.74	0	4.03	0.38	7.68	4.38	7.42	2.82	0	0	3.57	7.28	0	8.16
Tensolite	0	0	0	0.36	0.13	1.92	0	7.38	0.64	0	0	4.86	8.11	0.66	5.40
M81381	4.82	[illegible]	0	3.27	5.38	1.28	3.43	11.92	3.30	0	0	5.85	2.34	4.29	0
Thermatics	4.57	8.6[illegible]	0	0.30	0.10	5.79	3.85	11.74	1.58	0.56	0	5.32	4.99	9.77	6.54
NEMA #3	2.28	3.36	0	6.86	1.02	7.33	0	9.45	3.70	0	0	2.77	12.38	3.17	3.96
M22759	1.62	3.43	0	5.51	3.39	8.32	0	0	5.19	1.26	0	0.68	13.00	2.05	3.42

INSULATION CONSTRUCTION	DYNAMIC CUT THROUGH(FP)	FLEX LIFE(FP)	INSULATION IMPACT RESISTANCE	INSULATION TENSILE STRENGTH	NOTCH PROPAGATION(FP)	WIRE-TO-WIRE RUB	SMOKE QUANTITY	THERMAL INDEX	THERMAL SHOCK	VER. RET. PROP.	BSI DRY ARC PROP.	AVERAGE SCORE X 10
WEIGHT FACTOR	4.8	4.7	3.1	3.2	5.0	5.2	4.3	4.0	4.0	5.5	5.5	
Filotex	10.18	11.56	7.44	6.02	0	0	0.04	2.12	0.16	4.56	0	8.22
Tensolite	9.94	10.76	5.55	3.87	0	0	0.22	1.20	3.96	7.10	0.11	8.23
M81381	0	0	0	3.20	0	0	0	3.04	1.04	13.26	19.47	9.21
Thermatics	8.50	11.66	7.35	4.35	0	0	0	1.72	8.72	1.70	0.06	9.39
NEMA #3	8.69	6.91	2.39	6.34	0	5.82	3.48	7.00	0.44	8.74	9.62	10.48
M22759	12.00	11.28	5.18	5.38	0	3.95	10.71	10.88	0.28	6.49	0.06	11.38

SUM WEIGHT = 167.4
AVG WEIGHT = 4.1

(S) - Screening
(FP) - Full Performance

002-354.09

TABLE 6.3 - 22 AWG AIRFRAME WIRE OVERALL SUMMARY WEIGHTED

INSULATION CONSTRUCTION	WORKMAN-SHIP	EXAMINE PRODUCT	VOLTAGE WITHSTAND	INSULATION RESISTANCE	ABRASION(S)	DYNAMIC CUT THROUGH(S)	FLEX LIFE(S)	NOTCH PROPAGATION(S)	STIFFNESS AND SPRING BACK	FLAMMA-BILITY	TOXICITY	FINISHED DIAMETER	WIRE WEIGHT
WEIGHT FACTOR	3.0	3.0	5.5	4.5	5.5	4.5	5.5	5.0	4.2	4.3	5.0	4.2	4.2
M81381	0	6.90	0	0	10.07	0	0.50	0	17.18	0.34	16.15	0	0.46
Filotex	0	0	0	0	4.62	12.74	13.53	0	6.82	0.34	1.70	0	0.54
Thermatics	0	2.37	0	0	4.56	8.42	9.68	0	8.32	0.17	0.60	0	4.91
Tensolite	6.09	2.37	0	0	13.53	7.56	13.07	0	5.42	0.17	12.95	0	9.28
NEMA #3	3.06	6.90	0	0	15.40	6.12	9.74	0	7.39	2.06	0	0	1.76
M22759	3.06	4.62	0	0	14.80	13.64	14.90	2.80	5.08	7.61	5.10	0	5.26

INSULATION CONSTRUCTION	DIELECTRIC CONSTANT	AC CORONA	SURFACE RESISTANCE	TIME/CURRENT TO SMOKE	WET ARC TRACK	WIRE FUSE TIME	HUMIDITY RESISTANCE	WEIGHT LOSS	WEATHERING RESISTANCE	WICKING	ABRASION(FP)	COLD BEND	CRUSH RESISTANCE
WEIGHT FACTOR	2.0	3.3	2.2	3.3	3.2	3.2	4.5	2.2	3.5	3.5	5.2	3.3	3.0
M81381	4.72	3.43	0	5.31	5.38	2.24	12.06	3.30	0	0	1.09	4.29	0
Filotex	4.38	0.63	0	6.90	0.74	8.61	7.29	2.82	0	0	9.67	0	8.22
Thermatics	5.84	7.95	0	0	0	4.54	10.94	1.58	1.68	0	4.37	9.83	6.81
Tensolite	0	0	0	0.96	0.26	0	10.22	0.64	0	0	10.50	0.86	4.77
NEMA #3	3.70	4.06	0	6.90	0.26	7.07	10.94	3.70	0	0	12.90	3.73	3.81
M22759	3.62	1.45	0	7.62	4.03	8.03	0	5.19	1.68	0	13.31	1.72	0.99

INSULATION CONSTRUCTION	DYNAMIC CUT THROUGH(FP)	FLEX LIFE(FP)	INSULATION IMPACT RESISTANCE	INSULATION TENSILE STRENGTH	NOTCH PROPAGATION(FP)	WIRE-TO-WIRE RUB	SMOKE QUANTITY	THERMAL INDEX	THERMAL SHOCK	VER. RET. PROP.	AVERAGE SCORE X 10
WEIGHT FACTOR	4.8	4.7	3.1	3.2	5.0	5.2	4.3	4.0	4.0	5.5	
M81381	0	0	0	3.17	0	0	0	1.52	1.92	14.68	7.93
Filotex	12.34	12.64	8.28	6.94	0	0	0.13	0	0	7.86	9.53
Thermatics	8.06	12.97	7.04	3.17	0	0	0.04	0.96	9.12	4.18	9.55
Tensolite	10.90	11.56	5.86	4.03	0	0	0.04	2.40	2.08	11.44	10.16
NEMA #3	7.58	8.74	2.76	4.86	0	5.82	3.05	6.84	0.60	12.16	11.20
M22759	10.85	12.13	2.98	4.70	0	3.95	10.75	10.24	0.32	0	12.48

SUM WEIGHT - 144.6

(S) - Screening
(FP) - Full Performance

TABLE 6.3 - 22 AWG AIRFRAME WIRE OVERALL SUMMARY WEIGHTED

INSULATION CONSTRUCTION	WORKMANSHIP	EXAMINE PRODUCT	VOLTAGE WITHSTAND	INSULATION RESISTANCE	ABRASION(S)	DYNAMIC CUT THROUGH(S)	FLEX LIFE(S)	NOTCH PROPAGATION(S)	STIFFNESS AND SPRING BACK	FLAMMABILITY	TOXICITY	FINISHED DIAMETER	WIRE WEIGHT
WEIGHT FACTOR	3.0	3.0	5.5	4.5	5.5	4.5	5.5	5.0	4.2	4.3	5.0	4.2	4.2
M81381	0	6.90	0	0	10.07	0	0.50	0	17.19	0.34	16.15	0	0.46
Filotex	0	0	0	0	4.62	12.74	13.53	0	6.82	0.34	1.70	0	0.54
Thermatics	0	2.37	0	0	4.56	8.42	9.68	0	8.32	0.17	0.60	0	4.91
Tensolite	6.09	2.37	0	0	13.53	7.56	13.07	0	5.42	0.17	12.95	0	9.28
NEMA 63	3.06	6.90	0	0	15.40	6.12	9.74	0	7.39	2.06	0	0	1.76
M22759	3.06	4.62	0	0	14.80	13.64	14.90	2.80	5.00	2.61	5.10	0	5.26

INSULATION CONSTRUCTION	DIELECTRIC CONSTANT	AC CORONA	SURFACE RESISTANCE	TIME/CURRENT TO SMOKE	WET ARC TRACK	WIRE FUSE TIME	HUMIDITY RESISTANCE	WEIGHT LOSS	WEATHERING RESISTANCE	WICKING	ABRASION(FP)	COLD BEND	CRUSH RESISTANCE
WEIGHT FACTOR	2.0	3.3	2.2	3.3	3.2	3.2	4.5	2.2	1.5	2.5	5.2	3.3	3.0
M81381	4.72	3.43	0	5.31	5.38	2.24	12.06	3.30	0	0	1.09	4.79	0
Filotex	4.38	0.63	0	6.90	0.74	8.61	7.29	2.82	0	0	9.67	0	8.22
Thermatics	5.84	7.95	0	0	0	4.54	10.94	1.58	1.68	0	4.37	9.83	6.81
Tensolite	0	0	0	0.96	0.26	0	10.22	0.64	0	0	10.50	0.86	4.77
NEMA 63	3.70	4.06	0	6.90	0.26	7.07	10.94	3.70	0	0	12.90	3.73	3.81
M22759	3.62	1.45	0	7.62	4.03	8.03	0	5.19	1.68	0	13.31	1.72	0.99

INSULATION CONSTRUCTION	DYNAMIC CUT THROUGH(FP)	FLEX LIFE(FP)	INSULATION IMPACT RESISTANCE	INSULATION TENSILE STRENGTH	NOTCH PROPAGATION(FP)	WIRE-TO-WIRE RUB	SMOKE QUANTITY	THERMAL INDEX	THERMAL SHOCK	VERTICAL PROP.	AVERAGE SCORE X 10
WEIGHT FACTOR	4.8	4.7	3.3	3.2	5.0	5.2	4.3	4.0	4.0	5.5	
M81381	0	0	0	3.17	0	0	0	1.52	1.92	14.68	7.93
Filotex	12.34	12.64	8.28	6.94	0	0	0.13	0	0	7.86	9.53
Thermatics	8.06	12.97	7.04	3.17	0	0	0.04	0.96	9.12	4.18	9.55
Tensolite	10.50	11.56	5.86	4.03	0	0	0.04	2.40	2.08	11.44	10.16
NEMA 63	7.58	8.74	2.76	4.86	0	5.82	3.05	6.84	0.60	12.16	11.20
M22759	10.85	12.13	2.98	4.70	0	3.95	10.75	10.24	0.32	0	12.48

SUM WEIGHT = 144.6

(S) - Screening
(FP) - Full Performance

TABLE 6.4 - 22 AWG HOOK UP WIRE OVERALL SUMMARY - WEIGHTED

INSULATION CONSTRUCTION	WORKMAN-SHIP	EXAMINE PRODUCT	DRY ARC RESISTANCE	VOLTAGE WITHSTAND	INSULATION RESISTANCE	FLUID IMMERSION	ABRASION(S)	DYNAMIC CUT THROUGH(S)	FLEX LIFE(S)	NOTCH PROPAGATION(S)	STIFFNESS AND SPRING BACK	FLAMMA-BILITY	TOXICITY	FINISHED DIAMETER	WIRE WEIGHT
WEIGHT FACTOR	3.0	3.0	5.5	5.5	4.5	4.5	5.5	4.5	5.5	5.0	4.2	4.3	5.0	4.2	4.2
Tensolite	6.09	2.43	0	0	0	0.58	12.23	3.87	13.14	0	8.11	0	1.10	0	13.27
Filotex	0	0	6.60	0	0	1.04	2.75	10.12	12.76	0	8.27	0.43	0.80	0	0
MB1381	6.09	7.26	14.68	0	0	0.72	11.66	0	0.28	0	14.82	0	1.85	0	3.49
NEMA #3	0	7.26	5.06	0	0	0.32	16.02	3.82	11.11	0	9.20	1.68	8.00	0	2.31
Thermatics	6.09	2.43	6.60	0	0	0.45	6.22	6.70	12.37	0	8.88	1.55	3.85	0	7.22
M22759	0	2.43	5.88	0	0	0.22	15.90	11.70	14.46	5.00	3.04	3.36	0.95	0	3.99

INSULATION CONSTRUCTION	DIELECTRIC CONSTANT	AC CORONA	SURFACE RESISTANCE	TIME/CURRENT TO SMOKE	WET ARC TRACK	WIRE FUSE TIME	FORCED HYDROLYSIS	HUMIDITY RESISTANCE	WEATHERING RESISTANCE	WICKING	WIRE SURF. MARK	ABRASION(FP)	COLD BEND	CRUSH RESISTANCE
WEIGHT FACTOR	2.0	3.3	2.2	3.3	3.2	3.2	3.5	4.5	3.5	3.5	3.8	5.2	3.3	3.0
Tensolite	0	0	0	0	0	0	0	5.58	0	0	4.86	5.77	0.43	2.16
Filotex	1.47	3.17	0	5.21	0.06	8.35	5.46	6.80	0	0	3.57	4.84	0	8.25
MB1381	4.18	6.44	0	4.29	5.34	1.57	3.57	11.74	0	0	5.85	3.59	4.29	0
NEMA #3	2.70	4.55	0	5.44	1.79	5.73	0	8.64	0	0	2.77	11.91	2.57	1.86
Thermatics	4.56	8.35	0	0.53	0.19	4.64	3.96	12.10	0	0	5.32	5.67	9.74	6.84
M22759	0	4.95	0	8.78	2.75	8.26	0	0	2.14	0	0.68	12.74	2.38	3.51

INSULATION CONSTRUCTION	DYNAMIC CUT THROUGH(FP)	FLEX LIFE(FP)	INSULATION IMPACT RESISTANCE	INSULATION TENSILE STRENGTH	NOTCH PROPAGATION(FP)	SMOKE QUANTITY	THERMAL INDEX	THERMAL SHOCK	VER. RET PROP.	AVERAGE SCORE X 10
WEIGHT FACTOR	4.8	4.7	3.1	3.2	5.0	4.3	4.0	4.0	5.5	
Tensolite	7.97	11.28	3.66	3.71	0	0.04	0	0.76	9.84	7.57
Filotex	9.31	12.13	6.01	5.09	0	0.04	4.24	0.52	4.02	8.50
MB1381	0	0	0	3.20	0	0	4.60	0.64	15.73	8.79
NEMA #3	5.42	9.07	0.12	7.81	0	2.75	7.16	0	9.68	10.02
Thermatics	7.87	12.83	6.98	5.57	0	0	2.48	10.44	0	11.03
M22759	13.44	12.41	6.01	6.02	0	10.75	11.56	0.32	5.39	11.59

SUM WEIGHT = 154.5

(S) - Screening
(FP) - Full Performance

004-354.09

TABLE 6.5 - 26 AWG HOOK UP WIRE OVERALL SUMMARY - WEIGHTED

INSULATION CONSTRUCTION	WORKMANSHIP	EXAMINE PRODUCT	DRY ARC RESISTANCE	VOLTAGE WITHSTAND	INSULATION RESISTANCE	DYNAMIC CUT THROUGH(S)	FLEX LIFE(S)	NOTCH PROPAGATION(S)	STIFFNESS AND SPRING BACK	FINISHED DIAMETER	WIRE WEIGHT
WEIGHT FACTOR	3.0	3.0	5.5	5.5	4.5	4.5	5.5	5.0	4.2	4.2	4.2
M81381	3.78	2.22	15.29	0	0	0	4.56	0	13.25	0.46	0
Filotex	0	2.22	5.72	0	0	10.26	12.87	0	4.87	2.06	2.39
Tensolite	0	2.22	0	0	0	10.17	9.84	0	8.90	0.21	12.89
NEMA #3	7.56	6.63	0	0	0	11.25	0	0	6.66	0	4.24
Thermatics	0	0	5.72	0	0	9.72	8.42	0	6.07	0.46	4.79
M22759	7.56	2.22	5.72	0	0	13.59	12.92	13.30	3.26	0	2.02

INSULATION CONSTRUCTION	DIELECTRIC CONSTANT	AC CORONA	TIME/CURRENT TO SMOKE	WIRE FUSE TIME	FORCED HYDROLYSIS	HUMIDITY RESISTANCE	WEATHERING RESISTANCE	WICKING	CRUSH RESISTANCE
WEIGHT FACTOR	2.0	3.3	3.3	3.2	3.5	4.5	3.5	3.5	3.0
M81381	5.56	5.71	0.16	0	3.29	11.9'	0	0	0
Filotex	1.52	4.42	0	6.11	3.29	8.11	0	0	8.04
Tensolite	0	0	0.16	5.79	0	6.30	0	0	9.27
NEMA #3	0.94	3.30	8.25	9.22	0	8.78	0	0	6.24
Thermatics	3.18	9.54	0.36	8.22	3.74	12.24	0	0	5.94
M22759	1.22	3.89	0.16	8.70	0	0	0	0	5.73

INSULATION CONSTRUCTION	DYNAMIC CUT THROUGH(FP)	FLEX LIFE(FP)	INSULATION IMPACT RESISTANCE	NOTCH PROPAGATION(FP)	SMOKE QUANTITY	THERMAL SHOCK	VER. RET. PROP.	AVERAGE SCORE X 10
WEIGHT FACTOR	4.8	4.7	3.1	5.0	4.3	4.0	5.5	
M81381	0	0	0	0	0	0.52	9.35	6.90
Filotex	8.88	9.96	8.03	0	0	0	1.87	9.13
Tensolite	10.90	9.45	7.13	0	0.52	9.00	0	9.32
NEMA #3	13.06	2.96	4.31	0	4.60	0.76	4.40	9.35
Thermatics	9.55	9.16	8.03	0	0	6.64	0.94	10.22
M22759	11.66	9.35	6.54	0	10.58	0.16	14.02	12.42

SUM WEIGHT = 110.3

(S) - Screening
(FP) - Full Performance

TABLE 6.6 - S/J CABLE OVERALL SUMMARY - WEIGHTED

INSULATION CONSTRUCTION	WORKMAN-SHIP	FLAMMA-BILITY	TOXICITY	FINISHED DIAMETER	WIRE WEIGHT	TIME/CURRENT TO SMOKE	WEIGHT LOSS	WEATHERING RESISTANCE
WEIGHT FACTOR	3.0	4.3	5.0	4.2	4.2	3.3	2.2	3.5
Tensolite	4.26	0.56	6.75	0	13.69	5.18	0	0
M81381	0.42	0.73	1.15	0	0	7.85	6.03	0
M22759	2.22	4.47	4.15	0	6.22	0	1.28	1.68
Thermatics	0	0.34	8.85	0	8.32	4.95	0.75	1.68
NEMA #3	0	5.33	6.55	0	8.15	7.39	1.50	0
Filotex	-	-	-	-	-	2.51	1.58	0

INSULATION CONSTRUCTION	COLD BEND	FLEX LIFE(FP)	SMOKE QUANTITY	THERMAL SHOCK	AGING STABILITY	JACKET WALL THICKNESS	AVERAGE SCORE x 10
WEIGHT FACTOR	3.3	4.7	4.3	4.0	3.0	3.3	
Tensolite	1.45	0	0.58	3.04	0	1.88	7.15
M81381	7.33	10.95	0.38	5.76	0.93	3.70	8.65
M22759	1.98	9.87	5.94	4.84	0.48	2.97	8.81
Thermatics	6.83	8.93	0	2.40	0.93	2.38	8.86
NEMA #3	2.97	6.82	5.36	3.36	2.16	2.31	9.93
Filotex	0.46	9.12	0.13	3.80	0	4.42	-

SUM WEIGHT = 52.3

(FP) - Full Performance

7.0 AMENDMENTS 1 AND 2

Amendments 1 and 2 were separate contracts that were added to investigate arc propagation characteristics of the new aerospace constructions in a 270 volt dc power system.

Amendment 1 investigated the arc propagation characteristics of the insulation constructions when exposed to a short circuit in an unprotected 270 volt dc system. All 10 candidate insulations and the two baseline constructions were tested.

Amendment 2 investigated the arc propagation characteristics of inorganic insulation constructions to a short circuit in an unprotected 270 volt dc system. Three types of inorganic insulations were tested. In addition, the program investigated the ability of power controllers to inhibit arc propagation in a 270 volt dc system using the new wire insulation constructions. Six power controllers were evaluated with the four final candidate insulations and the two baseline constructions.

7.1 AMENDMENT 1: 270 VOLT DC DRY ARC PROPAGATION TESTS ON NEW INSULATION CANDIDATES.

7.1.1 Scope: The 270 volt dc Dry Arc Propagation Test on new insulation candidates was used to measure the resistance of the insulation to arcing and propagation of faults as a result of a short circuit in a 270 volt dc power system. No circuit protection was employed in order to determine the insulation's capability for extinguishing a 270 volt dc arc.

7.1.2 Reference Procedure: The 270 volt dc Dry Arc Propagation Test on new insulation and baseline candidates was performed using Method 301, of SAE AS 4373, as a guide. This test also included modifications for the grounding of the deflector plates and the first insulated harness clamp. There was no splaying of the conductors, no 36 gauge strand of wire to short the conductors together, and no circuit protection.

7.1.3 Specimens: The three wire harnesses, comprised of 20 wires each, used in the Dry Arc Resistance and Fault Propagation Test were reconfigured to be used for this test. All the harnesses were cut to a length of 42±1 inch in length except the harnesses of M81381 (102 and 103) which had to be rebuilt due to the damage sustained in the 115 volt ac and 28 volt dc Arc Propagation Test.

The wires used to construct the harnesses were 22 and 26 gauge, 5.8 mil wall, hook up wire with physical locations as shown in Figure 7.1. The wire description and power applications are described in Table 7.1. The harness integrity wires were not powered or grounded (they were left floating) and were included in the shorting end of the harness. The shorting end consisted of a quarter inch of conductor exposed on each wire with no splaying of the conductors. The last string tie of black Nomex lacing tape (MIL-T-43435 type B) was placed a half inch from the end of the insulation. The end of the harness that was connected to the input power terminal block had a quarter inch of insulation removed and a spade terminal crimped to each conductor.

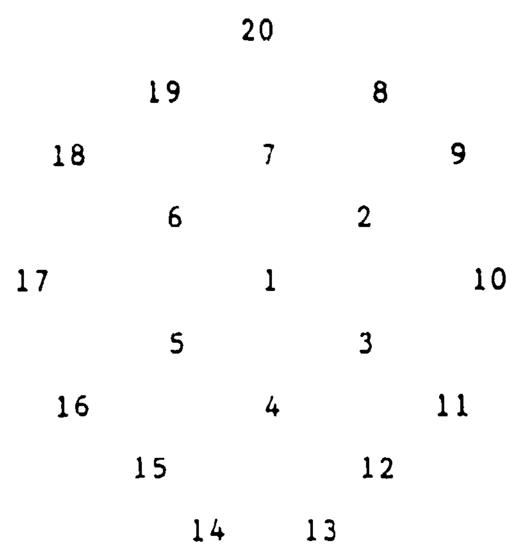

FIGURE 7.1 - WIRE LOCATIONS WITHIN THE HARNESS

TABLE 7.1 - WIRE LOCATION AND POWER TABLE

WIRE NO.	CONDUCTOR	POWER SOURCE
1	22 gauge, twisted pair	+ DC
2	22 gauge, twisted pair	- DC
3	26 gauge, twisted pair	+ DC
4	26 gauge, twisted pair	- DC
5	22 gauge	+ DC
6	22 gauge	- DC
7	22 gauge	+ DC
8	22 gauge	- DC
9	26 gauge	+ DC
10	22 gauge	- DC
11	26 gauge	+ DC
12	22 gauge	- DC
13	22 gauge	floating
14	26 gauge	floating
15	26 gauge	+ DC
16	22 gauge	floating
17	22 gauge	floating
18	22 gauge	- DC
19	26 gauge	floating
20	22 gauge	floating

7.1.4 Test Equipment: The power source used was a 270 volt dc, 30,000 Watt, Westinghouse Electric Corporation Generator (modified AV-8B aircraft generator) (P/N ED408067-001) with corresponding Generator Control Unit (P/N ED408068-001). The Generator Control Unit was configured to current limit the output of the generator to 289 amps. The generator was configured to drop off-line if a continuous short circuit existed for five seconds or more. The Main Line Contactor was a Hartman (Model A-75JD) 270 volt dc Power Contactor (S/N CH-83865) which was used to initiate the arc propagation test. Two lights were used to indicate whether the Generator was on line and when power was applied to the harness.

The deflector plate was a solid piece of 0.0125 inch

thick aluminum bent to a 90° angle so that the perpendicular segment was 2 x 12 inches and the parallel segment was 4 x 12 inches. The plate was connected to generator ground along with the first of two insulated harness clamps (MS21919WDG size 4) that supported the harness. The grounded harness clamp also had a 0.375 inch spacer placed between the clamp and the Bakelite back board.

The test was videotaped using a standard VHS tape recorder and camera and a Spin Physics High Speed Video System (2000 frames per second). The high speed video was down loaded to VHS tape after each specimen was tested.

The current duration was recorded on a Soltec (SMR) Signal Memory Recorder (MD 117327) using four Weston 450 amp / 50 millivolt shunts in conjunction with Preston Instrumentation Amplifiers. The test setup was configured to monitor the generator output current, generator return current through the harness, generator return current from the plates, and the generator return current from the clamp. The Preston Amplifiers were set for a gain of 100 and filtered to 10,000 Hertz. The output voltage of the generator was monitored through a ten to one voltage divider. An Equipment list is presented in Table 7.2.

Photographs of the test setup and generator are presented in Figures 7.4 through 7.7.

TABLE 7.2 - INSTRUMENTATION LIST

Soltec Channel	Measured Parameter	Weston Shunt 450 A / 50 mV (Serial Number)	Preston Amplifier (Serial Number)
1	Gen. Voltage	------	------
2	Harness Output Current	140731	071662
3	Harness Return Current	140729	071647
4	Reflector Plate Return Current	160156	071648
5	Clamp Return Current	140730	071661

7.1.5 Test Procedure: The harness was placed in the test setup with the test end of the harness placed at a distance of 0.0125 inch from the perpendicular segment of the grounded deflector plate and quarter inch from the parallel segment of the grounded deflector plate as shown in Figure 7.2.

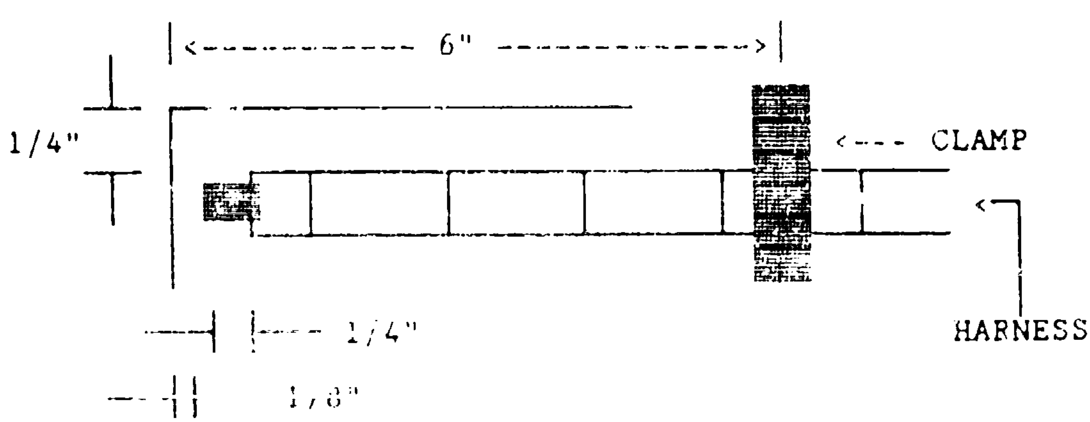

FIGURE 7.2 - HARNESS PLACEMENT WITHIN TEST SETUP

The generator was brought on line, the video recorders were started, the Soltec SMR was armed, and the Hartman contactor was closed to apply power to the harness. The test results were recorded using a high speed video system along with a standard video camera and VHS recorder. The Soltec SMR was used to acquire the current duration measurements.

After observing several tests, additional tie wraps were added to the harness to prevent the separation of wires which was extinguishing the arc. The first five inches of the harness had string ties placed at one inch intervals and at two inch intervals for the rest of the harness. This was done for the following harnesses:

M22759 (107 & 108)	Brand Rex (117 & 118)
Gore (132 & 133)	Filotex (137 & 138)
Tensolite (142 & 143)	Thermatics (147 & 148)
NEMA #2 (152 & 153)	NEMA #3 (157 & 158)

7.1.6 Test Results: All insulation constructions exhibited arc propagation. The "I" next to the length of charring value in Table 7.3 signifies that the insulation damage was intermittent throughout the length mentioned. Typically, damage was sustained at the shorting end of the harness and at the bend in the harness where it was connected to the circuit breaker chassis.

The average length of the 20 wire harness consumed in the test, average length of additional charring or blackening of the insulation, and the maximum short circuit current duration is presented in Table 7.3. A graphical representation of the short circuit current duration is presented in Figure 7.3.

It was concluded that none of the tested insulations were able to inhibit arc propagation in an unprotected 270 volt dc power system. Circuit protection devices are required to protect the interconnect system in a 270 volt dc power system.

TABLE 7.3 - UNPROTECTED 270 VDC HARNESS TEST RESULTS

SPOOL REF.	INSULATION CONSTRUCTION	TEST RUN	AVG. LENGTH CONSUMED (INCHES)	AVG. LENGTH OF ADD. DAMAGE (INCHES)	CURRENT DURATION (SECONDS)
102&103	M81381	A	1.00	2.00	1.747
102&103	M81381	B	3.50	28.50 I	2.406
102&103	M81381	C	6.00	29.00 I	2.739
107&108	M22759	*A	1.50	1.50	0.242
107&108	M22759	*B	5.00	29.50 I	2.157
107&108	M22759	*C	4.50	27.50 I	0.662
112&113	BARCEL #1	A	3.00	1.50	0.694
112&113	BARCEL #1	B	4.50	1.75	1.005
112&113	BARCEL #1	C	8.00	27.50	2.944
117&118	BRAND REX #1	*A	2.25	33.00	1.030
117&118	BRAND REX #1	*B	8.75	28.25	1.446
117&118	BRAND REX #1	*C	6.50	28.50	1.574
122&123	CHAMPLAIN #1	A	7.00	30.00	2.042
122&123	CHAMPLAIN #1	B	8.75	26.00	2.893
122&123	CHAMPLAIN #1	C	2.00	1.75	0.672
127&128	DUPONT #1	A	4.50	33.50	1.984
127&128	DUPONT #1	B	5.00	33.00	1.824
127&128	DUPONT #1	C	6.50	28.50 I	1.766
132&133	GORE #3	*A	8.00	27.50 I	1.824
132&133	GORE #3	*B	5.25	31.25 I	1.920
132&133	GORE #3	*C	12.50	22.50	2.086
137&138	FILOTEX	*A	6.00	32.00	1.894
137&138	FILOTEX	*B	4.00	33.50 I	1.306
137&138	FILOTEX	*C	3.00	30.00 I	2.112
142&143	TENSOLITE #3	*A	3.50	0.75	1.466
142&143	TENSOLITE #3	*B	1.00	0.50	0.381
142&143	TENSOLITE #3	*C	1.50	1.00	0.771
147&148	THERMATICS #3	*A	9.00	29.00	2.074
147&148	THERMATICS #3	*B	7.00	26.00	1.638
147&148	THERMATICS #3	*C	6.75	28.75 I	1.715
152&153	NEMA #2	*A	1.25	0.75	0.528
152&153	NEMA #2	*B	2.50	3.00	1.094
152&153	NEMA #2	*C	4.50	1.50	1.190
157&158	NEMA #3	*A	8.00	29.00	1.766
157&158	NEMA #3	*B	2.25	2.25	0.762
157&158	NEMA #3	*C	11.00	27.00	2.086

* = ADDITIONAL TIE WRAPS ADDED I = INTERMITTENT INSULATION DAMAGE

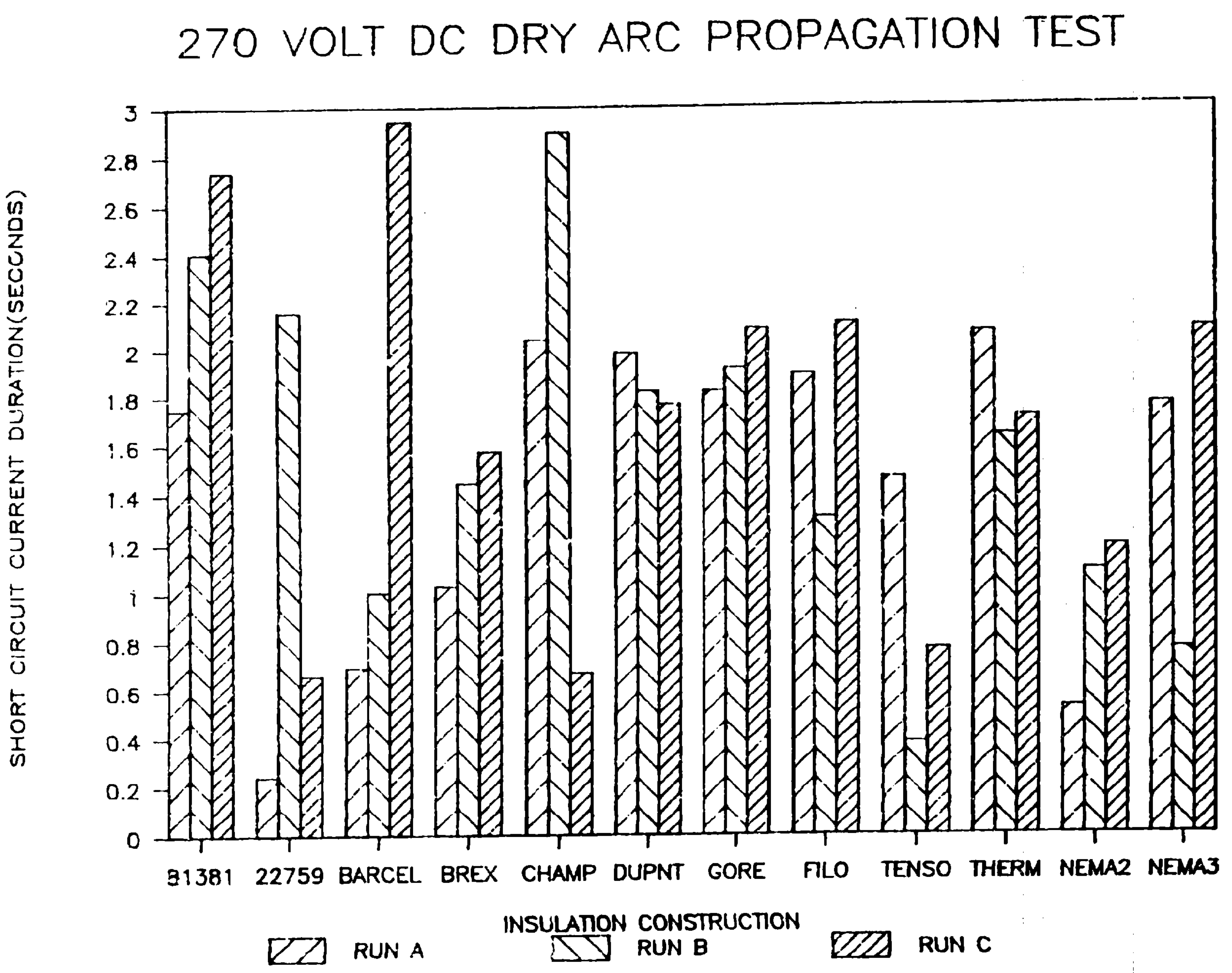

FIGURE 7.3 - SHORT CIRCUIT CURRENT DURATION TEST RESULTS

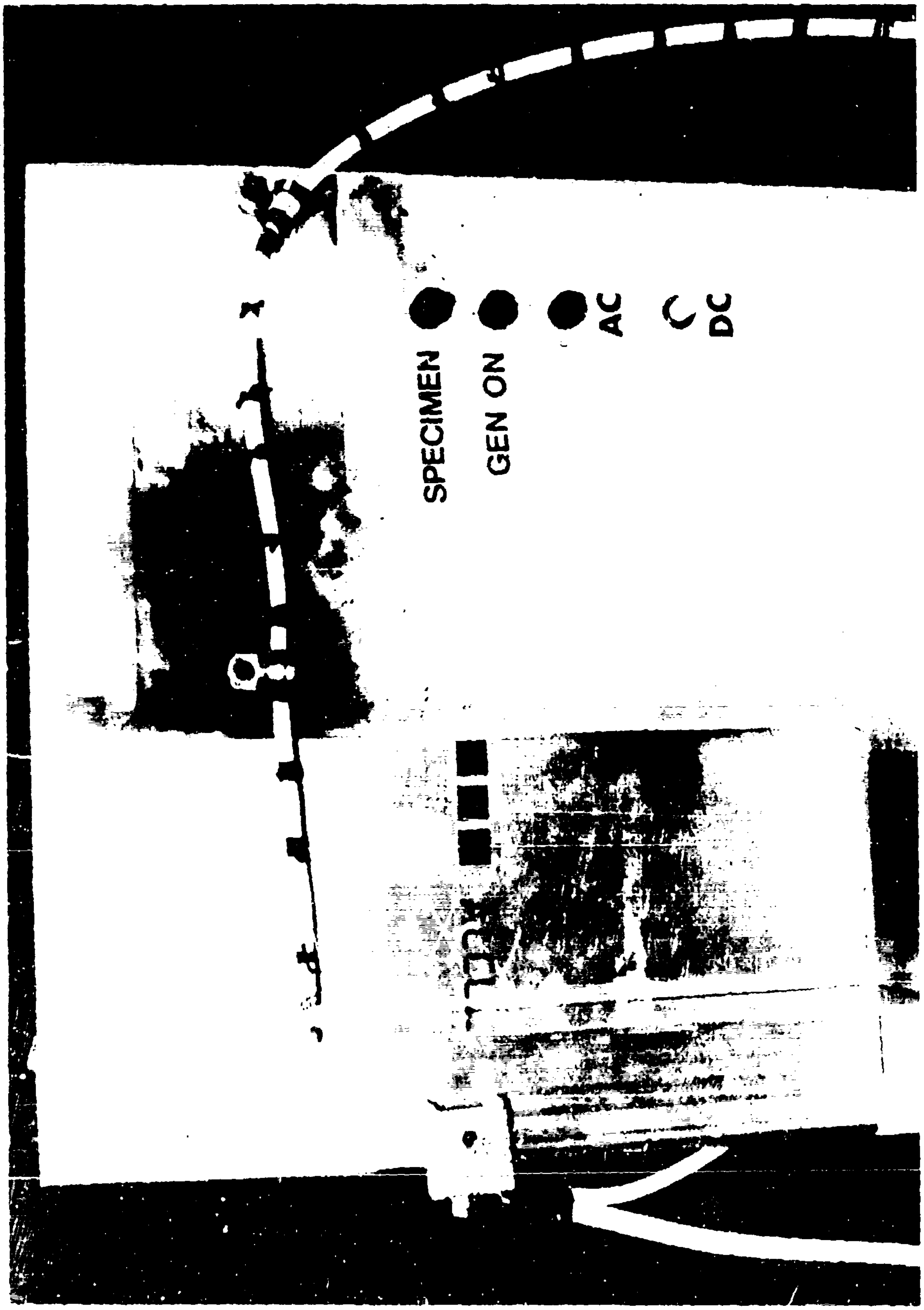

FIGURE 7.4 - HARNESS CONFIGURATION WITHIN TEST SETUP

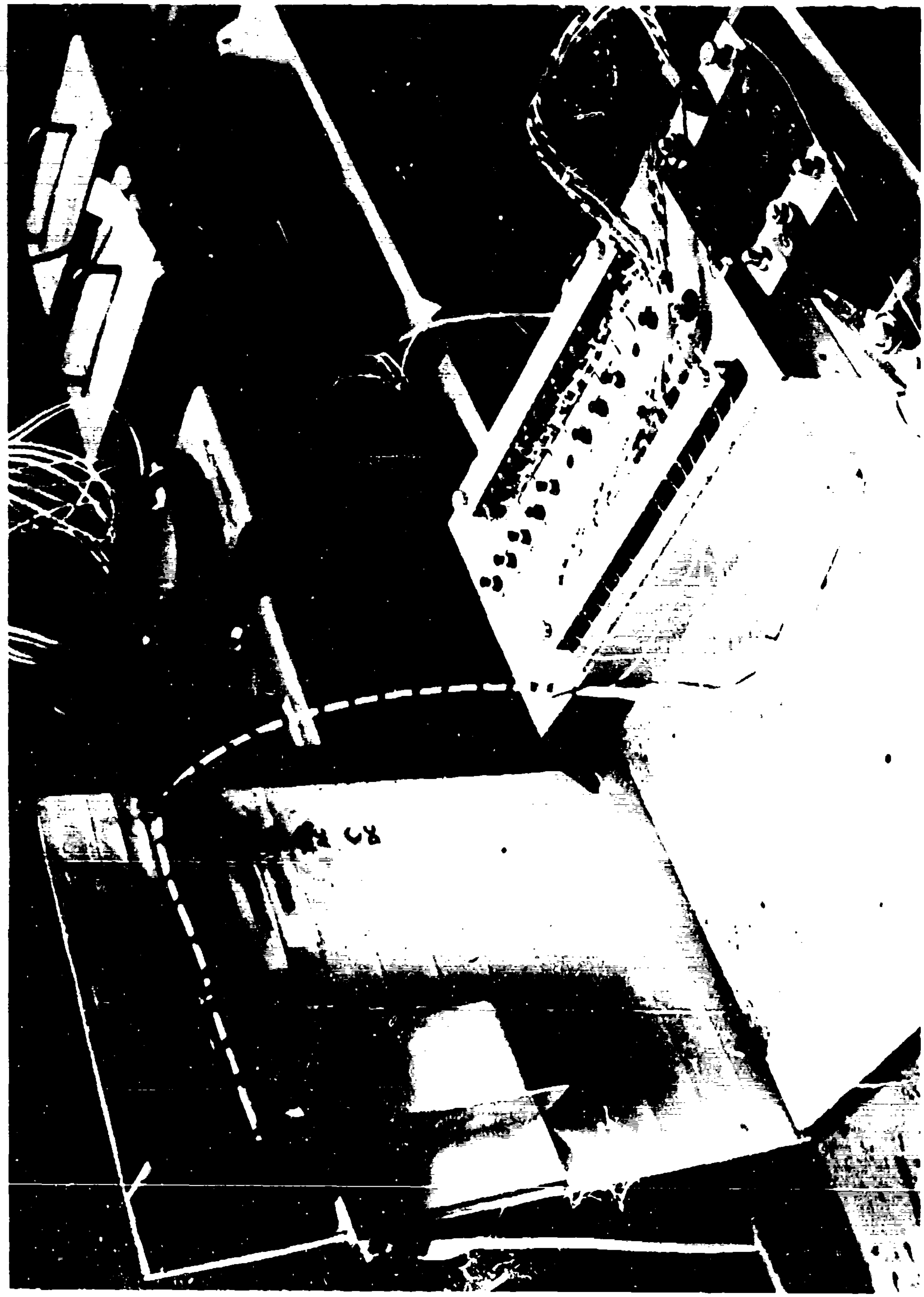

FIGURE 7.5 - HARNESS CONFIGURATION WITHIN TEST SETUP

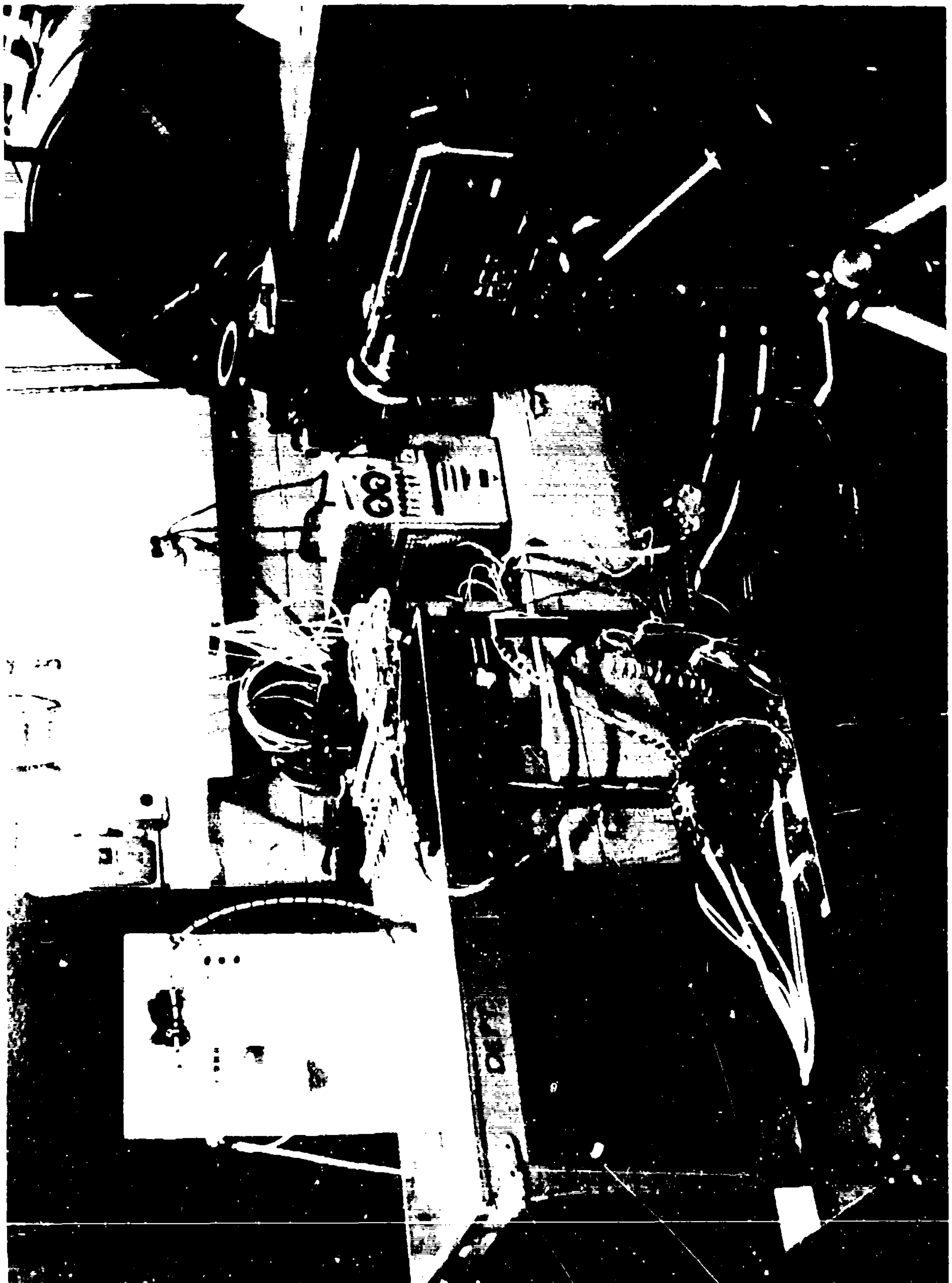

FIGURE 7.6 - 270 VOLT DC DRY ARC PROPAGATION TEST SETUP

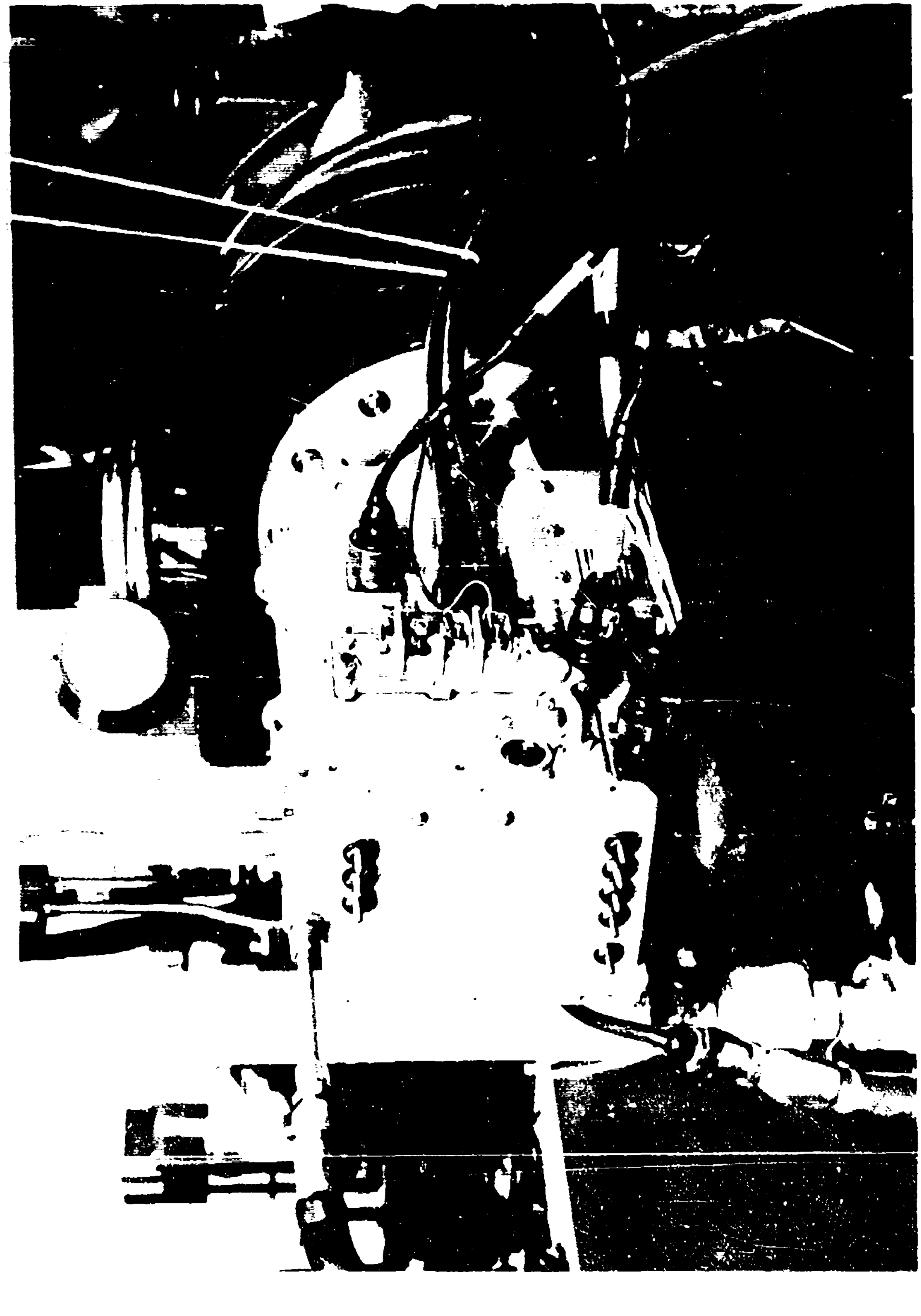

FIGURE 7.7 - 270 VOLT DC GENERATOR

7.2 AMENDMENT 2: 270 VOLT DC DRY ARC PROPAGATION TESTS ON UNPROTECTED INORGANIC HARNESSES AND NEW INSULATION CANDIDATES WITH POWER CONTROLLERS.

A copy of the Amendment 2 report is included as Volume II of this report.

8.0 ASSEMBLY, HANDLING, AND REPAIR TESTS

PERFORMED BY: DEPT. 156 WIRE HARNESS ASSEMBLY AREA

REPORT BY: KEVIN L. DETRING

1.0 SCOPE

The purpose of this test is to evaluate the two best wire types identified in CRAD Performance Tests in critical manufacturing processes. Characteristics of the wire types in assembly, handling, installation, removal and repairability will be determined.

2.0 SPECIMEN IDENTIFICATION

B Type - Control (M22759/33 & /44)

Spool Numbers:	207-	22 Thin
	208-	26 Thin
	209-	22-2SJ
	210-	26-2SJ

H Type - Filotex

Spool Numbers:	237-	22 Thin
	238-	26 Thin
	239-	22-2SJ
	240-	26-2SJ

I Type - Tensolite

Spool Numbers:	242-	22 Thin
	243-	26 Thin
	244-	22-2SJ
	245-	26-2SJ

3.0 TEST EQUIPMENT

Tooling and equipment as specified in McDonnell Aircraft Process Specifications.

4.0 PROCEDURE

Construction of harnesses shall be per Figures 1 and 2.

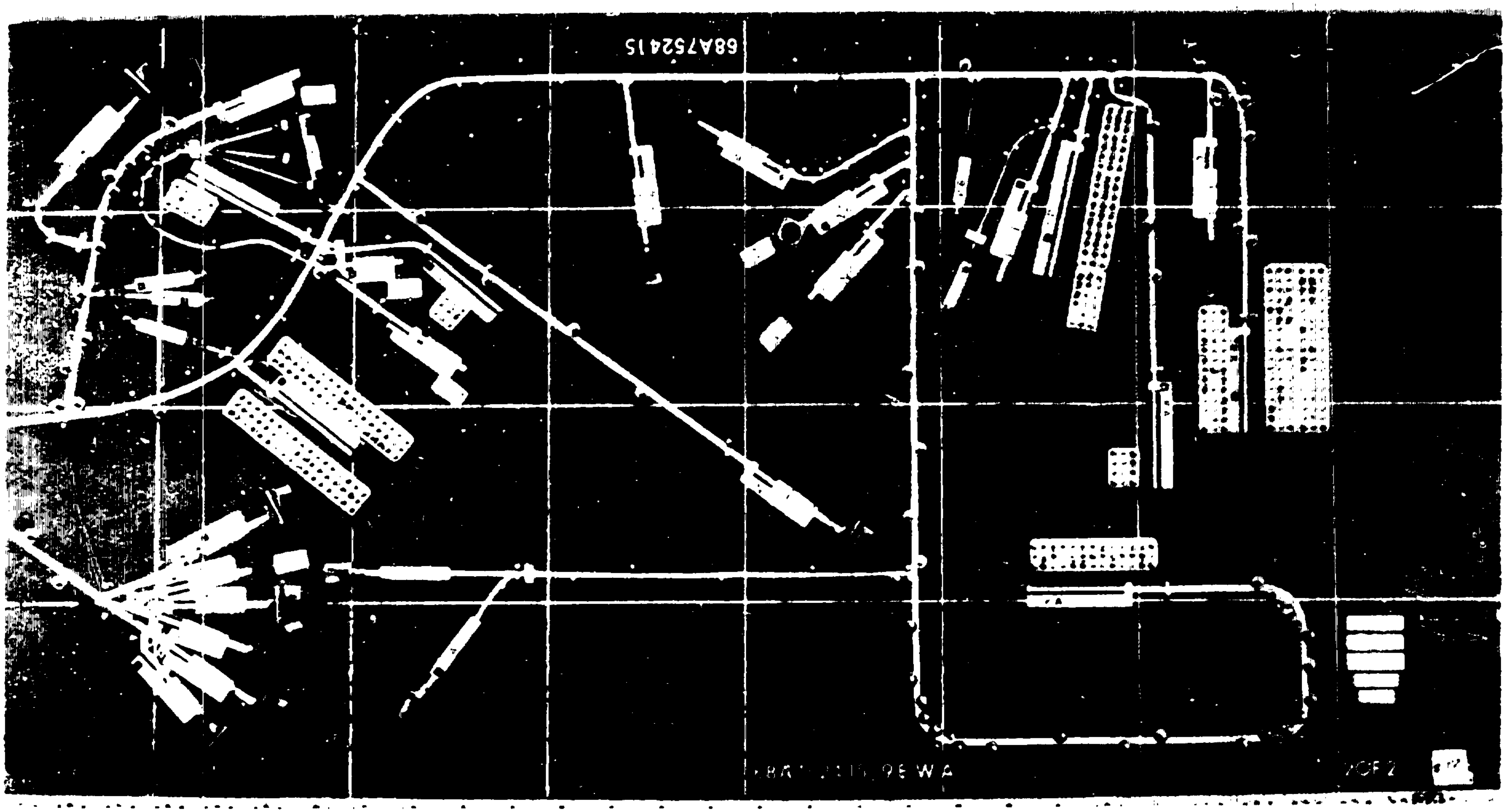

FIGURE 8.1 - WIRING LAYOUT BOARD FOR TEST HARNESSES

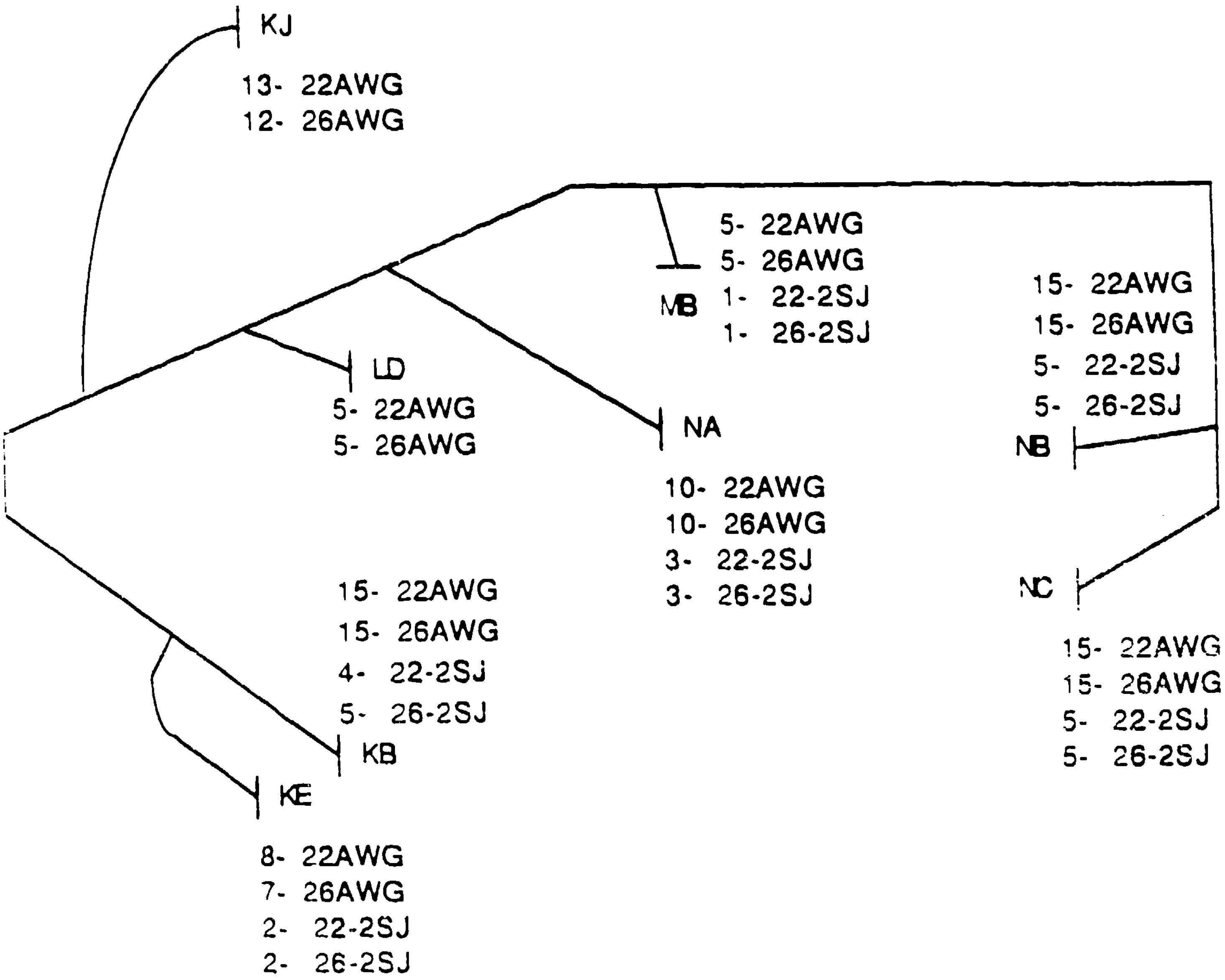

FIGURE 8.2 - WIRE/CABLE QUANTITY AND SIZE PER BRANCH

A. CONTROL HARNESS ("B TYPE")

(1) Cut wires to length.
(2) Apply MMS809 Thinwall shrink sleeves to all wire in branches NB and NC. Pay particular attention to sleeve slideability. The wire insulation should permit the sleeving to be moved along the wire by hand without wrinkling the insulation.
(3) Strip primary wires contained in branches KB and KE. Use existing tooling to strip the wire. Inspect stripped end for smoothness of cut and make sure that the strip tool does not nick the conductor.
(4) Fabricate shield splices to all shielded and jacketed cable contained in branches NB and NC. Use M22759/22-24 jumper wire. Pay particular attention to ease of shield push-back and how easily the shield can be combed out. Inspect jacket and primary insulation for damage due to the heat shrinking of the solder sleeves. Also, note ease of stripping the jacket.
(5) Apply routing tape to the wire. Pay particular attention to how well the routing tape adheres to the primary insulation and jacket insulation. Monitor the tape adherence throughout the layout and twisting process.
(6) Layout wire and cable on form board. Note handling characteristics.
(7) Twist and tape wire and cable. Note handling characteristics, such as how well the wire/cable holds its twist and how easily the wire/cable can be twisted.
(8) Braid harness using 200 denier Nomex. During braiding operation, visually verify that exceeding the bend radius requirements does not damage the wire/cable. Also, note ease of handling during the braiding operation.
(9) Using ST5M1345 splices, fabricate 10 splices with the primary wire in branch NA (five splices consisting of two 22 gauge wires and five splices consisting of two 26 gauge wires). Install 5M904 end caps. Visually inspect wire to verify that there is no damage to the wire insulation after shrinking the end caps.
(10) Follow step 4 for branches MB, NA, KB, and KE.
(11) Install and remove harness in aircraft. Note handling

characteristics. After removal, perform continuity and high-potential tests. Conduct the high-potential test from conductor to conductor and from conductor to shield using 1300 Vac (rms).

(12) Remove sections of Nomex braid from branches NA and MB using hot wire strippers and soldering iron. Visually inspect insulation for damage. On branch NA, cut five 22 gauge and five 26 gauge primary wires and repair per P.S. 17117 paragraph 6.6.1.1. Note repairability characteristics.

B. TEST HARNESS CONSTRUCTED USING "I TYPE" WIRE

(1) Repeat steps A(1) through A(12). Compare characteristics of the "I Type" wire to those of the control harness. Record comparisons in Table 3 by circling = if equivalent to the control, + if better than the control, or - if worse than the control. **If a + or - is circled, explain why in the comments section.**

(2) Fabricate 200 wired contact specimens using minimum length of 26 gauge wire required to conduct a tensile pull test. Use 100 pins and 100 sockets. Insert/remove 50 pins and 50 sockets a total of three times using hand insertion. At least 5 people should be involved in hand inserting the contacts. The other 100 contacts shall be inserted, using a tool, by at least five people. Insert/remove the contacts a total of 3 times. Visually inspect specimens to verify that there is no birdcaging or wire breakage. Conduct tensile pull tests on the 200 specimens and record the values so that a comparison between hand insertion and tool insertion can be made.

(3) Pot 25 etched one foot specimens (13-26 gauge and 12-22 gauge) with MIL-S-8516 polysulfide potting compound in a cup. Pot 25 non-etched specimens with polysulfide potting compound. For comparison purposes, pot 10 etched specimens using the control (five #207 and five #208) with polysulfide potting compound. Compare adhesion of the three test samples. Is etching necessary?

(4) Repeat step 3 except use MIL-S-23586 silicone potting compound.

C. TEST HARNESS CONSTRUCTED USING "H TYPE" WIRE

(1) Repeat all procedures in section B for "H Type" wire. For step 3, there is no need to pot up any more samples using the control wire. Compare the "H Type" wire to the "I Type" and record the comparisons in Table 3.

5.0 RESULTS

The results of the manufacturing evaluation are summarized in Table 3. An analysis for each area of assembly is detailed below.

A. WIRE CUT - Difficulties were encountered due to the small spools that the wire was on and the lack of spools. It was observed that both the "B" and "H Type" wire, if coiled on large spools, would present no major problems in wire cut. The "I Type" wire, however, exhibited extensive memory when coiled on small spool diameters and caused significant difficulties in the de-spooling process. Further evaluation using a standard spool would be necessary to determine the magnitude of the problem. The actual wire cut was satisfactory for all three wire types.

B. TMS SLEEVE INSTALLATION - The labor time to install sleeves for all three wire types was nearly identical. It was noted that the "H Type" was the stiffest wire and provided the easiest sleeve installation.

C ROUTING TAPE APPLICATION - The labor time to apply the routing tape on the wires was nearly identical for all

three wire types. In addition, there were no difficulties in the adherence of the tape on any of the wire types.

D. PEG AND BUNDLE - It was noted that the "I Type" wire had too much memory, thus, creating difficulties in combing and twisting the wire/cable. Also, the softness of the "B Type" caused the wires to adhere to each other. The "H Type" wire had less memory than the "I Type" making it easier to comb, twist, and coil.

E. FIRST TERM SOLDER SLEEVE - The following factored labor times were observed in the shield termination area:

B Type - 37 minutes
H Type - 42 minutes
I Type - 33 minutes

The "B Type" cable strips much harder than the "I" or "H Type" and a special tool must be used. The shield push-back of "B Type" is more difficult than that of the "I" or "H Type". The "I Type" has good shield push-back and combing as well as normal solder sleeve termination. On the "H Type" cable, the Teflon tape wrap adhered to the shield when the insulation was removed. The removal of this tape accounts for the additional labor time. The shield on the "H Type" cable was easy to work with in both push-back and combing.

F. STRIP AND CRIMP - No major differences were observed in stripping or crimping the three wire types.

G. WIRE HARNESS LAYOUT - The following factored labor times were observed in laying out the wire harnesses:

B Type - 91 minutes
H Type - 82 minutes
I Type - 90 minutes

Combing out of the "B Type" wire was the most difficult because the wires would tangle due to the soft insulation. "I Type" wire combed out better than "B Type", but the memory of the wire produced difficulties during routing. "H Type" wire lays in without overlap and combs out well.

H. <u>SLEEVE SLIDEABILITY</u> - The sleeve slideability of the "I Type" wire was extremely difficult. Occasionally, the insulation rolled over and was damaged. Sliding the sleeves on the "B Type" wire was slightly difficult due to the soft insulation. Sleeve slideability on the "H Type" wire was excellent and presented no difficulties.

I. <u>SECOND TERM SOLDER SLEEVE</u> - Observations were similar to those in first term solder sleeve. Again, the Teflon tape wrap on the "H Type" wire was the major difficulty.

J. <u>BRAID</u> - No major differences or difficulties were discovered during the braiding operation. Wire damage during braiding was not encountered.

K. <u>WIRE SPLICING</u> - In the fabrication of splices, no major differences or difficulties were observed between the three wire types.

L. <u>BUNDLE INSTALLATION/REMOVAL</u> - It was observed that the "B Type" harness was the most flexible of the three wire types. There was no significant difference in the flexibility of the "H" and "I Type" harnesses. The "I Type" harness tended to kink which could present installation difficulties or even damage the wire/cable. The "B" and "H Type" exhibited no kinking. It was again noted that sleeve slideability on the "I Type" wire was extremely difficult. A continuity check and high-potential test were conducted and no wire damage was detected.

M. <u>NOMEX REMOVAL & REPAIRABILITY</u> - The following observations were noted:

1) Braid removal using hot wire strippers:
   - B Type - Several of the wires had severe insulation damage.
   - H Type - No damage to wire insulation.
   - I Type - Several of the wires had depressions in the insulation.

2) Braid removal using a soldering iron:
   - B Type - Normal braid removal with no insulation damage.
   - H Type - Insulation turned blue when touched with soldering iron. This was easily wiped off and no damage to the insulation was observed.
   - I Type - Normal braid removal with no insulation damage.

3) Repairability characteristics observed:
   For the repair test, several wires were cut and spliced to new sections of wire. 5M904 end caps were used to cover the splices. There was no discernible difference in the repair of the three wire types. Repair was satisfactory and no difficulties were encountered.

N. <u>CONTACT INSERTION</u> - Results of the tensile pull test for "H Type" and "I Type" wire are shown in Table 1 and Table 2, respectively. McDonnell Aircraft Process Specifications require a minimum tensile value of 9 pounds for contacts crimped onto 26 gauge copper alloy wire. A small number of the contacts pulled below the minimum tensile value which raises the question of properly annealed crimp wells. Hand insertion produced similar results to tool insertion for "I Type" wire. The average tensile value for hand insertion of "H Type" wire was slightly less than the average obtained for tool

insertion but this variation could be due to the crimp. It was noted that in all cases, the contact pulled off of the conductor. There was no noticeable degradation of the wire due to the hand insertion process for either wire type.

O. POTTING ADHERENCE -

1) MIL-S-8516 polysulfide potting compound-
It was noted that the un-etched "I Type" wire adhered well to the potting. The wire did not etch well, so no improvements in adherence were observed by etching the "I Type" wire. The un-etched "H Type" wire was easily pulled out of the potting. The wire took etchant well which greatly increased the adherence to the potting. Therefore, etching is necessary on "H Type" wire but not on "I Type" wire.

2) MIL-S-23586 silicone potting compound-
The results were equivalent to those obtained using the polysulfide potting compound.

With the exception of the Teflon tape difficulty encountered during the shield splice operation, the "H Type" wire was the best performer of the wire harness fabrication evaluation. The "H Type" wire appears to be the most flexible and easiest to handle. "I Type" wire has extensive memory which caused handling difficulties in many areas of fabrication. It is stiffer than the "B Type" wire and therefore handles better than the "B Type" wire in areas such as identification sleeve installation, stripping, and crimping operations. It was determined that etching of the "I Type" wire is not necessary. The "B Type" wire was difficult to handle due to the wire softness and smooth jacket.

TABLE 8.1 - PULL TEST RESULTS FOR "H" TYPE 26 GAUGE WIRED CONTACTS

TOOL INSERTION				HAND INSERTION			
PIN (lbs)		SOCKET (lbs)		PIN (lbs)		SOCKET (lbs)	
14.6	13.0	16.3	12.4	13.2	12.9	19.2	12.9
19.2	12.5	12.8	13.6	11.7	12.1	20.1	10.5
14.5	12.5	15.1	13.9	14.2	13.7	6.0	15.7
13.1	15.5	17.8	14.9	12.2	13.2	18.0	12.4
12.4	13.5	13.3	17.0	13.2	14.1	14.9	14.2
15.0	13.6	17.1	17.2	13.4	12.7	14.7	16.1
13.0	13.6	13.8	9.7	12.9	13.4	13.7	11.7
14.3	14.0	17.1	16.2	11.0	14.6	12.4	10.2
12.7	13.1	16.2	8.4	12.7	11.5	15.4	17.5
14.4	12.2	14.0	14.4	14.4	13.9	11.7	22.5
14.0	12.2	18.6	11.7	13.9	11.5	20.5	11.0
14.5	15.0	17.1	14.7	11.5	12.0	10.5	18.0
14.8	12.6	13.6	15.4	12.7	12.4	12.0	14.4
11.8	12.3	11.3	14.2	10.0	11.7	12.4	14.9
13.5	13.8	17.1	12.4	12.0	13.2	11.2	17.2
14.5	15.0	13.6	19.0	14.2	12.7	15.6	13.5
12.8	13.3	17.6	12.7	13.2	14.2	10.5	12.7
11.5	15.0	8.6	17.7	13.7	12.2	13.4	15.4
13.5	13.6	13.3	21.0	12.2	12.1	11.2	13.5
12.6	13.0	15.8	12.4	14.9	12.7	12.7	16.1
13.3	15.3	10.3	14.4	13.4	11.5	12.9	13.2
12.3	14.6	14.0	15.4	11.0	18.0	11.2	12.7
13.5		14.0	23.2	14.7	12.6	12.1	9.5
12.7		10.9	14.9	14.1		17.0	12.4
12.8		15.0		13.2		13.5	
LOW = 8.6 HIGH = 23.2 AVERAGE = 14.2				LOW = 6.0 HIGH = 22.5 AVERAGE = 13.4			

TABLE 8.2 - PULL TEST RESULTS FOR "I" TYPE 26 GAUGE WIRED CONTACTS

TOOL INSERTION				HAND INSERTION			
PIN (lbs)		SOCKET (lbs)		PIN (lbs)		SOCKET (lbs)	
15.4	15.7	19.2	18.5	18.1	16.6	15.3	11.3
17.7	17.1	9.7	16.8	19.1	18.9	17.6	11.6
16.5	15.6	18.0	16.1	18.1	17.1	12.4	15.1
15.5	15.6	16.2	19.5	18.6	15.3	15.9	17.6
17.8	16.6	14.7	13.6	16.2	17.2	17.5	21.6
21.3	18.6	17.5	13.2	18.2	16.6	18.9	11.1
14.8	18.4	15.2	16.2	13.6	15.8	10.9	17.9
14.3	16.2	19.0	16.9	14.6	16.9	11.1	16.4
16.3	18.5	12.5	15.6	14.3	17.9	15.1	20.5
16.3	14.1	16.3	16.2	17.1	15.6	13.6	14.5
16.9	20.2	16.5	17.9	15.6	16.6	15.4	15.1
17.4	15.1	18.8	16.2	13.8	16.4	20.1	16.9
15.6	16.4	15.7	19.3	15.8	15.1	13.3	15.1
14.3	18.9	12.8	18.1	17.4	17.4	12.8	16.2
15.8	17.9	20.1	18.3	18.2	15.1	12.0	19.1
17.1	15.8	21.3	16.2	17.1	15.6	17.3	14.3
13.1	16.9	16.7	8.0	17.6	19.1	20.1	16.0
15.1	18.1	8.5	16.4	14.1	14.3	18.1	17.1
16.9	15.6	16.3	11.7	19.4	16.2	16.1	16.4
16.4	16.2	16.6	19.4	15.6	14.3	11.3	16.1
14.3	15.1	14.3	16.6	19.5	16.2	13.9	
15.0	14.1	20.5	15.3	16.4	14.3	15.5	
13.8	16.0	13.0	19.4	16.9	15.6	13.3	
15.7	14.8	8.7		16.8		15.3	
14.3		17.5		16.2		14.3	
LOW = 8.0 HIGH = 21.3 AVERAGE = 16.1				LOW = 10.9 HIGH = 21.6 AVERAGE = 16.0			

TABLE 8.3 - EVALUATION SHEET FOR NEW WIRE INSULATIONS

STEP #	STEP DESCRIPTION	"I TYPE" VS "B TYPE"			"H TYPE" VS "B TYPE"			"H TYPE" VS "I TYPE"		
(2)	Sleeve Slideability									
	- Ease of Sliding Sleeve By Hand	-	+	-	-	+	-	-	+	-
(3), (9)	Primary Wire Strippability									
	- Smoothness of Cut	-	+	-	-	+	-	-	+	-
	- Strippability Without Nicking Conductor	-	+	-	-	+	-	-	+	-
(4), (10)	Fabrication of Shield Splices									
	- Ease of Shield Push-back	-	+	-	-	+	-	-	+	-
	- Ease of Shield Combing	-	+	-	-	+	-	-	+	-
	- Shrinking of Solder Sleeve Without Damaging Insulation	-	+	-	-	+	-	-	+	-
(5)	Routing Tape Application									
	- Adherence of Tape	-	+	-	-	+	-	-	+	-
(6)	Wiring Layout									
	- Handling Characteristics	-	+	-	-	+	-	-	+	-
(7)	Twisting and Taping									
	- Handling Characteristics	-	+	-	-	+	-	-	+	-
(8)	Bundle Braiding									
	- Ability to Braid Without Wire Damage	-	+	-	-	+	-	-	+	-
	- Handling Characteristics	-	+	-	-	+	-	-	+	-
(9)	Wire Splicing & End Cap Shrinkage									
	- Shrinking of End Cap Without Insulation Damage	-	+	-	-	+	-	-	+	-
(11)	Bundle Installation/Removal									
	- Handling Characteristics	-	+	-	-	+	-	-	+	-
(12)	Nomex Removal & Repairability									
	- Ease of Removal Using Hot Wire Strippers	-	+	-	-	+	-	-	+	-
	- Ease of Removal Using Soldering Iron	-	+	-	-	+	-	-	+	-
	- Removal Without Insulation Damage	-	+	-	-	+	-	-	+	-
	- Repairability Characteristics	-	+	-	-	+	-	-	+	-
	NUMBER OF -, +, OR - PER COLUMN	10	6	1	10	7	0	10	7	0

Can 26 gauge "I Type" wire be hand inserted? yes/no "H Type"? yes/no

Is etching of "I Type" necessary for polysulfide potting? yes/no Silicone? yes/no

Is etching of "H Type" necessary for polysulfide potting? yes/no Silicone? yes/no

9.0 CHEMICAL AND THERMAL ANALYSIS TESTS

9.1 SUMMARY. The thermo-oxidative aging of two new electrical wire constructions, one fabricated by Filotex, the other by Tensolite, were compared with the aging characteristics of two in-service qualified constructions, M81381 and M22759. The constructions were aged at 200°C (392°F) for time periods up to 1600 hours and changes in the properties of the insulation were measured by four physical analytical methods: (1) thermogravimetric analysis (TGA), (2) differential scanning calorimetry (DSC), (3) vaporization gas chromatography (VGC) with mass spectrometry (MS), and (4) mechanical stress/strain. The changes in the conductor were monitored by Auger spectroscopy coupled with argon bombardment depth profiling.

The M22759 construction shows the most changes during aging, the other three constructions age much less. All systems except one show a pronounced loss in mechanical properties after high temperature aging. In several instances, plasticizers and/or anti-oxidants are lost during aging but most of the base resins do not appear to show appreciable degradation at the conditions employed in these studies.

9.2 INTRODUCTION. The large increase in the avionics and the fly-by wire concept in modern aircraft has mandated the use of large quantities of electrical wire. Modern high-performance aircraft such as the F-15 and F-18 use more than 30,000 meters

(100,000 feet) of electrical wire. The large amount of material coupled with the total energy requirements place a severe limit on the overall properties of the wire: it must be low volume, light weight, i.e., the conductor diameter must be minimal; the insulation must exhibit excellent dielectric properties; and it must be thermally stable for prolonged periods of time, i.e., 200°C (392°F) for 10,000 hours.

Although several materials such as the aromatic polyimide [poly(n,n'(p,p'-oxydi-phenylene pyromellitimide)] sold under the trade name Kapton (DuPont) and qualified in aerospace wire as M81381 or irradiated ethylene tetrafluoroethylene (XL-ETFE) qualified in wire as M22759 are acceptable, new materials with better overall capabilities are required.

One of the major considerations in the selection of any wire system is its ability to withstand the rigors of the harsh aerospace environment which consists of a complex mixture of heat, humidity, stress, fatigue, and solvents which are applied either singularly or in combinations. Nevertheless, as a first test of long-term stability, a wire system must show little or no signs of degradation after 10,000 hours at 200°C (392°F).

Degradation is a complex process, characterized by chemical and/or physical changes (aging) which can, and in most cases does, occur. Chemical changes include such effects as oxidation, production of volatile products and crosslinking while physical changes may be more subtle, such as loss of plasticizer or antioxidant, or change in the free volume which

may be even more detrimental to the long-term mechanical properties of the material.

The only sure test of a material in the real environment is real time aging. However, this is lengthy and a very complex process which requires the material in question to be used in the real environment. Thus, simulated aging or accelerated aging methods must be found. Eventually the data obtained in the simulated environment must be compared with real-time data. At the present time, no generally accepted method exist to either age materials in an accelerated manner or to evaluate them after some form of aging. However, at a very minimum, it is necessary that the constructions used in modern aircraft retain most of their desirable properties after being subjected to high temperature, thermo-oxidative environment. The studies reported herein utilized two temperatures; 200°C (392°F), the upper maximum long-term use temperature, and 229°C (444°F), an accelerated aging temperature to be used to simulate long-term effects. The constructions were analyzed before and after aging by a variety of physical, analytical methods to determine changes in both the insulation and in the plated conductor. All the conductors except one, the Filotex 138, were silver plated over copper, the 138 was nickel plated over copper.

9.3 EXPERIMENTAL SECTION. We have utilized a combination of several different thermoanalytical, chemical, physical, and mechanical tests to evaluate selected wire constructions

before and after aging. Two new wire systems selected by MCAIR following extensive tests and two qualified systems, M81381 and M22759 were evaluated. Three specific constructions of each type were tested.

Twelve separate wire constructions were tested: it is quite evident that a "test matrix" can become too large to handle in a limited program where 12 constructions are tested if all the various aging parameters are considered. Therefore, two aging temperatures, the long-term upper temperature, 200°C (392°F) and an accelerated value at 229°C (444°F), were selected. All samples were aged at both temperatures and the constructions which were aged at the higher temperature were analyzed first. If the analysis of the high temperature aged construction showed no change compared to the unaged sample, some of the low temperature analysis, particularly the complex vaporization gas chromatographic analysis, was not conducted. The constructions studied are summarized in Table 9.1.

Due to the complex nature of the constructions used in the various insulations, i.e., each insulation uses several different materials, a direct comparison between the different constructions is difficult, but changes in a given construction as a function of aging are quite useful.

9.3.1 AGING PROCEDURE. The wires were thermally aged in air inside regulated ovens: one oven was set and controlled at 200°±2°C (392°±5°F) and the other at 229°±2°C (444°±5°F).

Approximately three feet of each wire cut into four inch sections was placed in a metal pan inside the environmental chamber. Individual pieces were removed for analysis as needed. The wires aged at 200°C (392°F) were analyzed after aging for 838 and 1655 hours; the wires aged at 229°C (444°F) were analyzed after 838 and 1508 hours.

9.3.2 ANALYSIS.

9.3.2.1 DIFFERENTIAL SCANNING CALORIMETRY (DSC). The use of DSC to characterize polymer systems is a well-known technique which is used to determine the glass transition temperature of amorphous resins, the melting point and degree of crystallinity of partially crystalline materials, and the onset of exo- or endothermic reactions within the resin systems. DSC is probably the best known of the "thermal analysis" methods in which the energy flow (heat) to a sample is monitored during a programmed temperature change. A small sample of insulation, (typically 5-10 milligrams), is placed in a special aluminum cup which is crimped shut and analyzed in a DSC system (DuPont 9900). The differential power between the sample cell and a reference cell is measured directly. The parameters of interest are the melting point of the crystals, the area of the melting curve and the stability of "flatness" of the baseline. The area and shape of the melting curve is an indication of the degree of purity of the crystals and the area is proportional to the degree of crystallization.

9.3.2.2 THERMOGRAVIMETRIC ANALYSIS (TGA). TGA is also a well-known method used for polymer analysis; it is primarily used to determine high-temperature thermal stability. During the analysis procedure, the change in weight (normally a loss) of a small sample, typically 40 milligrams, is continuously monitored while the temperature is increased at a linear rate. TGA analysis is restricted to weight loss and gives an indication of the temperature at which the material begins to degrade. It also can be used to determine the amount of unreactive, i.e., inert, filler which the particular resin contains. Changes in the TGA curve can be used to monitor changes in the degradation process during aging. A DuPont 951 TGA is used in conjunction with the 9900 for this analysis.

9.3.2.3 VAPORIZATION GAS CHROMATOGRAPY (VGC)/MASS SPECTROMETRY (MS). In vaporization gas chromatography (VGC) analysis, between 30 and 40 milligrams of sample is heated in a desorption oven at a specific temperature for a fixed length of time while an inert gas stream flows over the sample to desorb the indigenous volatile compounds. Typical desorption temperatures are 100 to 350°C (212 to 662°F) and typical desorption times are 20 to 30 minutes. The exact conditions are chosen to optimize the release of indigenous volatile compounds while at the same time minimizing the chance for thermal degradation of the sample. A cryogenic trap is located between the desorption oven and a chromatographic column. This trap is maintained at liquid nitrogen

temperatures during the sample desorption period, thus freezing the volatile compounds desorbed from the sample.

After the desorption period is complete, the sample is removed from the desorption oven and isolated from the trap and column. After the column carrier gas flow has equilibrated, liquid nitrogen is removed from the trap and the column oven is warmed. Since the trap is in the column oven, the mixture of compounds desorbed from the sample and frozen on the trap is separated chromatographically and detected with a flame icnization detector.

If desired, the outlet of the column can be connected to the mass spectrometer transfer line thus permitting mass spectral data to be obtained on the eluting compounds. This data can be used to identify the organic material. If compounds are evolved from the sample below pyrolysis temperatures, i.e., less than 300°C (572°F) for most organic materials, then they are assumed to arise from indigenous materials trapped in the sample. If compounds are evolved from the sample above pyrolysis temperatures, i.e., greater than 300°C (572°F), then they are assumed to arise from thermal degradation of the sample.

9.3.2.4 SCANNING AUGER SPECTROSCOPY. Scanning Auger Spectroscopy is a surface analytical technique which is used to determine the elemental composition of the top few atomic layers of a sample's surface. A Perkin Elmer PSI Model 600 was used for all the analyses. Because the technique is so

surface sensitive, analysis is carried out in an ultra high vacuum system so that gas molecules do not adsorb on the surface and interfere with analysis. During analysis, the sample is irradiated by the primary electron beam, causing Auger electrons to be emitted from the sample. Thus, conductors are good candidates for Auger analysis, insulators generally cannot be analyzed, and semiconductors usually can be analyzed. To determine the elemental composition of the surface, the spectrometer energy-analyzes the electrons being emitted from the sample. The Auger electrons are only a small fraction of the total secondary electron current being emitted from the sample. Thus, a plot of electron intensity versus energy for a large energy range is usually displayed as the first derivative, and such a plot is called a survey scan.

The primary electron beam is controlled the same way an electron beam on a scanning electron microscope (SEM) is controlled. In fact, SEM images can be made with the scanning Auger equipment, although they do not have quite as good lateral resolution as most electron microscopes. The primary beam can be rastered over a specified area of a sample to determine the elemental composition of that area, or points can be picked on the sample and the composition of those points determined. A lateral resolution of ten μm is easily achieved and a resolution of a few μm is possible. Auger mapping can also be accomplished by moving the electron beam over the sample while monitoring signal from a particular element yielding a picture of the distribution of that element

over the sample surface.

An additional feature of the Auger analysis chamber is the ability to argon ion bombard the surface being analyzed, and thereby remove material from the sample surface. A sputter profile involves monitoring the Auger electron signal from a few elements as the sample is sputtered away by the argon ion beam indicating the variation in the sample composition as a function of depth. The sputtering can be stopped at any time during the profile and a survey scan or map acquired, and then the profile continued. Mapping in this fashion gives three-dimensional information about the sample composition.

9.3.2.5 MECHANICAL ANALYSIS. The mechanical properties of the insulations were measured with a Polymer Laboratories Minimat MKII Miniature Material Tester. The insulation is carefully stripped from small, approximately one inch long, pieces of wire, and analyzed in the Minimat coupled with a Compaq Deskpro 336/20E computer for complete data processing. The insulation was clamped into the system and the stress-strain curves measured at ambient temperature (approximately 23°C (73°F)) at a cross-head speed of one millimeter per minute. A 1000 Newton load cell was used in all measurements. The data is directly recorded as stress (Newton per millimeter squared, N/mm^2) and strain (millimeter per millimeter, mm/mm).

One must exert considerable caution when comparing stress-strain curves from different constructions, but the changes observed on a particular system during environmental aging can be useful. Nine of the 12 constructions investigated are tape wound and the stress measured is actually a combination of tensile and shear forces required to pull overlapping tape regions apart. The M22759 constructions (numbers 206, 207, 208) are extruded polymer and the measured force is much closer to the actual tensile force required to deform the polymer. Nevertheless, these tests can be used to evaluate the overall loss of properties of a given system due to the deleterious effects of thermal aging.

The stress (σ), is equal to force (F), divided by the cross-sectional area of the insulation (A), (with the conductor removed), and the strain (ϵ), is the engineering strain, i.e., change in length (Δl) divided by the original length (l_o):

$$\sigma = F / A \qquad (1)$$

$$\epsilon = \Delta l / l_o \qquad (2)$$

9.4 RESULTS. Separate experiments were conducted to determine the effects of thermal oxidative aging on the insulation and the conductor although it must be noted that the entire wire system was exposed to the aging environment. The properties of the insulation which were measured are:

1. Thermal stability by thermogravimetric analysis (TGA)
2. Structure by differential scanning calorimetry (DSC)
3. Chemical changes (i.e., either loss of indigenous material or the production of degradation products) by vaporization gas chromatography (VGC) with mass spectrometry (MS)
4. Mechanical by stress-strain mechanical analysis

Changes in the surface chemistry of the conductor were monitored by Auger spectroscopy.

9.4.1 THERMOGRAVIMETRIC ANALYSIS (TGA). A typical TGA weight loss curve from the #136 Filotex sample is shown in Figure 9.1. This figure contains several curves, the TGA curve of the unaged insulation and that of the same material aged at 229°C (444°F) for 838 and 1508 hours. However, in order to best view the changes which occur during aging, the curves are more conveniently shown in the derivative form. The derivative form of the curves shown in Figure 9.1 are shown in Figure 9.2. The data and conclusions drawn from the TGA study are summarized in Table 9.2. Both the Filotex (136-138) and the Tensolite (241-243) constructions exhibit little or no change in high temperature thermal stability after aging. The M81381 (Kapton based) systems (201-203) exhibit several weight loss peaks. Construction 201 has two weight loss peaks, one at 500°C (932°F) and one at 580°C (1076°F); the former increases during aging. The 202 construction shows three

weight loss peaks; at 500°C (932°F), 575°C (1067°F), and 600°C (1112°F) which do not appreciably change during aging. All the M81381 based constructions show a large, approximately 60% wt., non-volatile/inert fraction. Construction 203 shows the same three weight loss peaks observed in 202 which also are independent of aging.

All the M22759-based constructions show marked changes in aging: the effect being most pronounced in construction 206. The initial sharp peak in the unaged material at 473°C is degraded into three peaks at 365°C (689°F), 425°C (797°F), and 460°C (860°F) after aging. This corresponds to a marked change. After aging, a small peak at approximately 370°C (698°F) is observed in construction 207 and the primary peak at 485°C (905°F), for unaged wire, is reduced to 470°C (878°F).

Although 208 construction does degrade due to aging, it is less than that observed in either the 206 or 207 constructions.

9.4.2 DIFFERENTIAL SCANNING CALIMETRIC ANALYSIS (DSC). The DSC thermograms of each of the 12 constructions unaged and after thermal oxidative aging were recorded. As an example, the DSC curve for Filotex 136 is shown in Figure 9.3. All the DSC data is summarized in Table 9.3. Two melting endotherms were observed in the Filotex 136-138 samples; the larger of the two, which is the lower melting, occurs at about 316°C (599°F) and the other occurred at approximately 330°C (626°F).

This is recorded as 316/330 in the table and the areas of the melting endotherms are recorded similarly. The ratio of the two compounds giving rise to these two endotherms is different in the three Filotex constructions; the effect of aging is also different. The Tensolite constructions, 241-243 exhibit a single relatively sharp endotherm at 325°C (617°F). The M81381 constructions all exhibit a single small endotherm at approximately 265°C (509°F) corresponding to the melting of the FEP interlayer adhesive; Kapton is a thermoset resin with no melting point. The M22759 constructions all exhibit a large melting endotherm at approximately 265°C (509°F). Both constructions 207 and 208 show a relatively broad distribution of the melting endotherm in the unaged sample which is changed during aging. The sharper endotherm following aging suggests that the crystalline distribution is more uniform in the aged than in the unaged material.

9.4.3 MECHANICAL ANALYSIS. The stress-strain data from each of the 12 constructions was recorded and an example of Filotex 136 is shown in Figure 9.4. The unaged and aged samples are shown for comparative purposes. The quantities of interest are the yield stress (σ_y), and yield strain (ϵ_y), and the failure stress (σ_f), and failure strain (ϵ_f). In several cases, there is no obvious yield and only the failure values are listed. In most cases, the failure occurs either in the clamp or at the clamp edge. The data is summarized in Table 9.4. The Filotex samples (136-138) all exhibit a marked

decrease in their mechanical properties during aging. The failure stress decreases 37%, 41% and 10% while the failure strains decrease 83%, 65%, and 37% for the 136, 137, and 138 constructions, respectively. In most cases, yield occurs at the tape overlap due to degradation of the interply adhesive.

The Tensolite constructions (241, 242, 243) also show degradation in mechanical properties although not as severe as observed in the Filotex constructions. The decrease in failure stress was 37%, 32%, and 32% for Tensolite constructions 241, 242, and 243, respectively. Construction 241 exhibited an unusual aging effect, the extension to fail markedly increased after aging at 200°C (392°F). Because of the unusual nature of this phenomenon, the measurements were repeated on other sections of wire with essentially the same results. The constructions do not show evidence of failure but they appear to yield after extensions greater than 200%. One must be careful about interpreting percent loss, particularly if the initial values are high.

The reference M81381 samples all yield at the tape overlap representing degradation of the interply adhesive. The 202 construction undergoes very little degradation during aging and its aged mechanical properties are nearly identical to those of the unaged material.

All of the M22759 constructions exhibit a marked color change during aging, progressing from white to tan to dark brown. They all undergo catastrophic failure, usually either in the clamp or at the clamp edge. Short term aging, i.e.,

838 hours at 200°C (392°F) appears to increase the mechanical properties of sample 208.

A direct comparison of the aging characteristics of different constructions based on the stress-strain data is at best qualitative and no major conclusions can be drawn from this data alone.

The initial strength of the Filotex 136 and 137 are similar and greater than the thinner 138, however 137 appears appreciably stronger after aging. The unaged Tensolite 241-243 are similar, but 243 (the thin wall) is the strongest. After aging, 241 is significantly better than either 242 or 243. The unaged M81381 constructions are all essentially the same, however, after aging, the 202 construction is significantly stronger. In the initial unaged state, 206 is the best of the M22759 constructions, however, after aging, the differences in the three constructions are much less even though 206 is still the best.

9.4.4 **AUGER ANALYSIS OF CONDUCTOR.** The various wire constructions and the types of insulators used in the construction have a dramatic effect on the aging of the conductors inside the wire. A previous study, Stability of Irradiated ETFE Insulated Electrical Wiring, MDC QA017, demonstrated the diffusion of copper to the surfaces of silver coated copper conductors, and that the copper is found as an oxide on the silver plating. In the present study, these same phenomenon are again observed on silver coated conductors, and

in addition they are observed on a nickel coated conductor. We studied sixteen samples, some aged and others unaged (virgin), using Scanning Auger Microscopy (SAM) to document the chemical changes on the conductors' surfaces and Scanning Electron Microscopy (SEM) to document the physical changes on the conductors' surfaces. The samples were manually striped of their insulation to expose the conductors before SAM and SEM analysis.

An example of a recorded Auger spectrum is presented in Figure 9.5 for an unaged Filotex 138 sample. Test data for all samples is summarized in Table 9.5 for quick comparison. In the table, the box for each sample has the elements detected on the unsputtered surface listed across the top of the box in order of decreasing intensity of the Auger peak height. Next are listed the elements detected after ion milling approximately 600Å into the surface of the conductor (sputtering six min. will remove approximately 600Å of material). The unaged samples are all seen to have a high carbon content when compared to the aged samples. One of the unaged samples (243) shows some copper diffusion even with no aging. This is presumably due to heating during processing.

Comparison of the 22 and 26 gauge wires aged at 229°C (444°F) for 1508 hours (the left most columns on the table) shows no correlation. In the case of the Filotex samples, the conductor was nickel coated in the 22 gauge wire and silver coated in the 26 gauge wire. Thus, comparison of copper diffusion in these two cases is obviously complicated by the

fact that it is diffusing through different materials. In the other samples, even though the conductors are all silver coated, one must still be concerned that the coating thickness, grain size, residual stress, etc. may be different in the different gauges. Thus, the best insulator materials/constructions for one gauge wire may differ from the best choice for another gauge wire. Unfortunately, we do not yet understand the mechanism of this relatively low ...perature, 229°C (444°F), copper diffusion in these ...rials, and thus no explanation can be offered as to why the different gauge wires behave so differently. A better understanding of the basic science of surface segregation phenomenon in a non-inert ambient is needed to explain this data.

In a comparison of the 26 gauge wire data, there are clearer trends in the data. The Filotex Cu/Ag ratio after six minutes of sputtering is zero for all three sample treatments. The small amount of copper diffusion which occurred in this construction was completely removed from the surface by sputtering approximately 600Å of material off the surface. The worst case was the M22759 construction which showed a Cu/Ag ratio after six minutes sputtering of greater than 0.5 for both of the aged samples. The M81381 and Tensolite constructions were somewhere in between. However, for the 22 gauge wires, the M22759 was the best construction based on Cu/Ag peak height ratios after six minutes of sputtering.

Aging tends to produce either a rough, bumpy surface (e.g., samples 243 and 138), or a rough, charred-looking surface (e.g., sample 208), or a combination of the two (e.g., sample 203) when examined through a scanning electron microscope. A longer aging time may increase the roughness of the conductor surface, but the type of roughness remains the same.

9.4.5 CHEMICAL ANALYSIS BY VAPORIZATION GAS CHROMATOGRAPHY / MASS SPECTROMETRY (VGC/MS). A wire sample, complete with conductor, was cut from the roll to obtain a mass of insulation of about 30 milligrams. The sample was then subjected to a two-step heating process to desorb indigenous volatile compounds of chromatographic analysis: (1) 20 minutes at 200°C (392°F) followed by (2) 20 minutes at 300°C (572°F). This sequence of heats was performed for all samples in this study.

For as-received samples, the two-step heating process was useful to determine the ease with which indigenous compounds could be driven out of the sample. This is particularly important in light of the temperature rating of the insulation and the thermal aging parameters used in this study. The results of VGC studies of the as-received wire insulation are summarized in Table 9.6.

The compounds which are desorbed during these two heating periods are indigenous materials trapped in the polymer matrix. These compounds may be produced during synthesis or

processing, low molecular weight oligomers, or solvents remaining from fabrication, or contamination; or they may be purposely added in either of the above processes to control plasticity, inhibit oxidation, enhance fire-resistance, and so on. If both the initial heat and second heat have an L or M, then these indigenous materials are readily desorbed from the wire construction. If the initial heat has a T, then little of the indigenous material is desorbed for the short time at the certified upper use temperature.

In all cases, the differences in chromatograms between wire constructions within a group were mostly in the relative amounts of the various compounds desorbed. Therefore, VGC/MS was only performed on one wire construction of a group normally the one which evolved the greatest amount of material in the two heats. The volatile compounds desorbed from the Filotex constructions fall primarily into two classes: (1) fluoro-hydrocarbons, and (2) alkylesters of linear aliphatic acids. One would suspect that the first class of compounds are due to residual chemistry and the second are additives. The relative proportions of these compounds changes between the two heats.

The compounds evolved from the Tensolite constructions also fall into two classes: (1) aliphatic hydrocarbons, and (2) the same alkylesters seen in the Filotex constructions. The aliphatic hydrocarbons are probably waxy die lubricant used in the wire fabrication.

The volatile material from the M81381 construction is characterized by two classes of compounds as well: (1) A mixture of the isomers of propyl- and butyl-benzenes and (2) the dimethyl esters of short chain aliphatic diboric acids. In addition, this construction may release N-methylphyrolidone, but this cannot be unequivocally determined without a separate analysis on a different chromatographic column. A small amount of the alkylesters seen in the other wire constructions mentioned above is also present. Interestingly, most of this material is evolved in the second, higher temperature heat of the wire sample.

The compounds evolved from the M22759 construction are primarily a mixture of fluoro-hydrocarbons. Both the number of compounds and the amount released from this construction is greater than in any of the other wires analyzed. These are primarily lower molecular weight compounds either produced during synthesis or during wire fabrication. None of the aliphatic esters detected in the other constructions is seen here. There are, however, several oxygen containing species with molecular weight in the range of 250 to 300 daltons are present. These compounds are probably additives.

In summary, analysis of the as-received wire constructions shows they behave alike in that they all have indigenous compounds, some of which are unintentionally left in the polymer, some of which are purposely added to the resin. In all of these constructions, heating to 200°C (293°F) for 20 minutes is sufficient to desorb many of these

compounds.

VGC analysis of thermally aged samples was performed and the results compared with the as-received data. Since the primary thrust of this portion of the study was to search for possible thermal degradation of the insulation, this work was limited to analysis of samples aged in air at 229°C (444°F). If no evidence of degradation of the base polymer could be found at this temperature, then it was not necessary to analyze the samples aged at lower temperatures.

For almost all of the samples studied, the number and amount of compounds evolved during VGC analysis decreases after aging 838 hours. After aging 1500 hours, however, most chromatograms showed more compounds were observed than after aging 838 hours. Frequently, these compounds eluted at different times than those observed in the as-received wire constructions, suggesting that some thermal degradation may have occurred.

Mass spectrometry of the VGC analyses was performed to identify the compounds from thermally aged wire constructions. In this phase of the study, attention was focused on the two new systems (i.e., the Filotex and Tensolite constructions). In the Filotex series, the aged samples have several chromatographic peaks which elute from 58 minutes to 61 minutes which were either not present in the analysis of the as-received samples or were in very low concentration. These compounds are unsaturated oxygen containing hydrocarbons. None contain fluorine. This suggests that they may be formed

by the thermal degradation of additives.

Mass Spectrometric analysis of the Tensolite series indicates that only one or two new peaks appear in the aged sample. One is a lower mass homolog of the alkyl ester of the long chain aliphatic acid. The other is a highly substituted alkyl phenol. These are not likely products from the thermal degradation of the compounds known to be present in the as-received insulation. Either it is very tenaciously held in the matrix or it is an impurity.

These results indicate that the chemistry which occurs in these thermally aged wire formulations is limited primarily to the additives used by the vendors. It should also be noted that the sensitivity of the VGC technique is such that it will detect chemical changes at extremely low levels. Thus, the small chemical changes we observe here do not appear to indicate any large scale chemical degradation of the base polymers following thermal aging for 1500 hours at 229°C (444°F). However, it is important to note that VGC analysis is based on the assumption that volatile compounds will be formed during an aging experiment. Other chemical reactions, such as cross-linking, which do not lead to volatile compounds are more readily observed by their effect on other properties, such as stress/strain.

9.5 DISCUSSION. The aging observed in the various constructions can be summarized with respect to the method of analysis used to measure the changes which occur. The

observations are summarized in Table 9.7. The M22759 series of constructions changed significantly during aging. These changes were evident in all five analytical methods used to study the aging process. The largest change in the conductor occurred in the 208 construction where copper not only diffused to the surface but was still observed after prolonged sputtering (i.e., depth profiling).

The mechanical properties of all the constructions were degraded during aging. Two points are important, (1) the room temperature mechanical properties of M81381 (202) construction were essentially unchanged after aging and (2) some of the room temperature mechanical properties of the M22759 (208) actually increased following aging for 1600 hours at 200°C (392°F).

Apparently little of the base resins used in any of the constructions is degraded during aging. The primary effects of high temperature aging are fourfold: (1) loss or destruction of the adhesive used to seal the tapes, (2) loss of certain volatile species such as anti-oxidants, (3) embrittlement (cross-linking) of extruded resins such as ETFE, and (4) in some instances copper may diffuse through the silver (or nickel) plated conductor.

TABLE 9.1 - WIRE CONSTRUCTIONS EVALUATED IN THIS STUDY

SPOOL REF.	INSULATION CONSTRUCTION	GAUGE	TYPE	COLOR	DESCRIPTION
136	FILOTEX	22	A	White	5.2 mil PTFE / 2.4 mil 616 / 1.0 mil PTFE (top coat)
137	FILOTEX	22	H	White	2.4 mil PTFE / 2.4 mil 616 / 1.0 mil PTFE (top coat)
138	FILOTEX	26	H	White	2.4 mil PTFE / 2.4 mil 616 / 1.0 mil PTFE (top coat)
241	TENSOLITE	22	A	White	5.0 mil 200 AJ919 / 4.0 mil PTFE
242	TENSOLITE	22	H	Green	2.4 mil 200 AJ919 / 4.0 mil PTFE
243	TENSOLITE	26	H	Black	2.4 mil 200 AJ919 / 4.0 mil PTFE
201	INDEPENDENT	22	A	Green	M81381/11-22-5
202	TENSOLITE	22	H	Opaque Yellow	M81381/7-22-N
203	BARCEL	26	H	Tan	M81381/9-26-N
206	BAND REX	22	A	White	M22759/43-22-5
207	CHAMPLAIN	22	H	Green	M22759/44-22-9
208	BRAND REX	26	H	White	M22759/33-26-9

A = AIRFRAME WIRE, 8.6 MIL WALL
H = HOOK UP WIRE, 5.8 MIL WALL

TABLE 9.2 - SUMMARY OF TGA AGING STUDIES

SPOOL REF.	INSULATION CONSTRUCTION	* AGED n/°C	ONSET OF WT LOSS (°C)	MAX RATE OF WT LOSS (°C)	NONVOLATILE INERT %	COMMENTS
136	FILOTEX	0/	540	584	12	little change
136	FILOTEX	838/229	541	590	17	
136	FILOTEX	1508/229	536	583	16	
137	FILOTEX	0/	538	586	11	little change other than increase in non-volatile fracture
137	FILOTEX	838/229	540	584	14	
137	FILOTEX	1508/229	543	582	19	
138	FILOTEX	0/	539	585	15	little change other than increase in non-volatile fracture
138	FILOTEX	838/200	534	582	18	
138	FILOTEX	1655/200	541	586	20	
138	FILOTEX	838/229	540	580	17	
138	FILOTEX	1508/229	539	584	29	
241	TENSOLITE	0/	547	591	11	little change
241	TENSOLITE	238/229	544	590	13	
241	TENSOLITE	1508/229	553	598	11	
242	TENSOLITE	0/	542	589	18	little change
242	TENSOLITE	838/229	543	588	17	
242	TENSOLITE	1508/229	544	588	13	
243	TENSOLITE	0/	542	591	13	little or no change
243	TENSOLITE	838/200	544	589	15	
243	TENSOLITE	1655/200	543	591	13	
243	TENSOLITE	838/229	545	592	14	
243	TENSOLITE	1508/229	546	585	14	
201	M81381	0/	-	502/580	53.9	Two weight loss peaks increase in 504° peak with aging
201	M81381	838/229	-	504/580	54.2	
201	M81381	1508/229	-	500/580	48.7	
202	M81381	0/	-	499/575/596	58.3	No change
202	M81381	838/229	-	504/577/599	61.3	
202	M81381	1508/229	-	499/579/598	60.3	
203	M81381	0/	-	494/574/596	60.8	No change
203	M81381	838/200	-	501/579/596	61.1	
203	M81381	1655/200	-	499/575/595	62.5	
203	M81361	838/229	-	499/575/598	61.9	
203	M81381	1505/229	-	501/577/598	61.9	

* AGED n/°C = NUMBER OF HOURS EXPOSED TO THE DESIGNATED TEMPERATURE

TABLE 9.2 - SUMMARY OF TGA AGING STUDIES (CONT.)

SPOOL REF.	INSULATION CONSTRUCTION	* AGED n/°C	ONSET OF WT LOSS (°C)	MAX RATE OF WT LOSS (°C)	NONVOLATILE INERT %	COMMENTS
206	M22759	0/	446	473	21.7	At least three major degradation products produced during aging
206	M22759	838/200	?	465	36.1	
206	M22759	838/229	320	364/426/460	26.1	
206	M22759	1508/229	326	361/426/461	25.6	
207	M22759	0/	380	420/480	12.0	New wt loss peaks formed by aging. Wt loss begins at ~310°, main stability reduced to 465°C
207	M22759	838/200	320	370/470	0.0	
207	M22759	838/229	310	360/465	15.3	
207	M22759	1508/229	310	365/465	12.0	
208	M22759	0/	379	410/488	13.3	Small wt loss at 410° evolves to wt loss at 360°C
208	M22759	838/200	304	364/475	36.0	
208	M22759	1655/200	307	362/475	10.0	
208	M22759	838/229	331	361/475	36.0	
208	M22759	1508/229	331	367/477	15.3	

* AGED n/°C = NUMBER OF HOURS EXPOSED TO THE DESIGNATED TEMPERATURE

TABLE 9.3 - DIFFERENTIAL SCANNING CALORMETRIC ANALYSIS OF AGED WIRE CONSTRUCTIONS

SPOOL REF.	INSULATION CONSTRUCTION	* AGED n/°C	ENDOTHERM(S) TEMP (°C)	ENDOTHERM(S) AREA (J/g)	COMMENTS
136	FILOTEX	0/	316/330	6.0/1.7	Small or no change
136	FILOTEX	838/229	317/330	4.8/2.2	
136	FILOTEX	1508/229	318	4.5/1.6	
137	FILOTEX	0/	317/330	6.2/0.7	Little change
137	FILOTEX	838/229	318/331	6.3/0.4	
137	FILOTEX	1508/229	318/330	6.0/0.7	
138	FILOTEX	0/	317/330	2.6/3.8	Little change except for the ratio of the high to low melting endotherm
138	FILOTEX	838/200	318/330	2.8/3.1	
138	FILOTEX	1655/200	319/330	2.5/2.7	
138	FILOTEX	838/229	318/330	3.6/2.4	
138	FILOTEX	1508/229	319/330	3.5/2.4	
241	TENSOLITE	0/	324	15.1	Little change
241	TENSOLITE	838/229	325	16.2	
241	TENSOLITE	1508/229	325	13.6	
242	TENSOLITE	0/	325	12.6	Little change
242	TENSOLITE	838/229	325	14.1	
242	TENSOLITE	1508/229	325	13.0	
243	TENSOLITE	0/	324	15.2	Little change
243	TENSOLITE	838/200	324	16.0	
243	TENSOLITE	1655/200	324	13.2	
243	TENSOLITE	838/229	324	15.7	
243	TENSOLITE	1505/229	324	13.2	
201	M81381	0/	262	2.7	Little or no change
201	M81381	838/229	262	3.2	
201	M81381	1505/229	260	2.8	
202	M81381	0/	262	1.3	No change
202	M81381	838/229	257	1.6	
202	M81381	1505/229	256	1.5	
203	M81381	0/	262	1.3	No change
203	M81381	838/220	260	1.5	
203	M81381	1655/200	257	1.1	
203	M81381	838/229	260	1.4	
203	M81381	1508/225	261	1.3	

* AGED n/°C = NUMBER OF HOURS EXPOSED TO THE DESIGNATED TEMPERATURE

J/g = JOULES PER GRAM

TABLE 9.3 - DIFFERENTIAL SCANNING CALORMETRIC ANALYSIS OF AGED WIRE CONSTRUCTIONS (CONT.)

SPOOL REF.	INSULATION CONSTRUCTION	* AGED n/°C	ENDOTHERM(S) TEMP (°C)	ENDOTHERM(S) AREA (J/g)	COMMENTS
206	M22759	0/	260	27.4	Broad endotherm
206	M22759	838/200	264	31.9	Aging increases
206	M22759	838/229	268	37.9	crystallite order
206	M22759	1505/229	270	30.8	
207	M22759	0/	263	30.6	Broad endotherm
207	M22759	838/200	264	35.6	Aging increases
207	M22759	838/229	268	35.0	crystallite order
207	M22759	1505/229	269	33.2	
208	M22759	0/	259	32.5	Very broad
208	M22759	838/200	361	34.5	endotherm
208	M22759	1655/200	261	33.7	Aging increases
208	M22759	838/229	266	28.8	crystallite order
208	M22759	1505/229	267	29.0	

* AGED n/°C = NUMBER OF HOURS EXPOSED TO THE DESIGNATED TEMPERATURE

J/g = JOULES PER GRAM

TABLE 9.4 - MECHANICAL TESTING OF AGED WIRE CONSTRUCTIONS

SPOOL REF.	INSULATION CONSTRUCTION	* AGED n/°C	YIELD STRESS (N/mm^2)	YIELD YIELD %	FAILURE STRESS (N/mm^2)	FAILURE STRAIN %	COMMENTS
136	FILOTEX	0/	51	45	57	103	Yield at tape edge, sharp failure
136	FILOTEX	838/200	-	-	50	55	Yield at tape edge, failed in clamp
136	FILOTEX	838/200	40	30	40	48	Yield at tape edge, failed at clamp
136	FILOTEX	1508/229	36	15	36	18	Failed at clamp
137	FILOTEX	0/	50	27	63	80	Yields in stages, failed at clamp edge
137	FILOTEX	838/200	50	42	50	48	Yield at tape edge, failed at clamp
137	FILOTEX	838/229	24	42	37	90	Failed at tape edge
137	FILOTEX	1508/229	38	22	37	25	Yield at tape edge, failed at clamp
138	FILOTEX	0/	20	50	67	52	Yield at tape edge, failed at clamp
138	FILOTEX	838/200	59	30	58	32	Yield at tape edge, failed in clamp
138	FILOTEX	838/229	-	-	61	34	Sharp failure
138	FILOTEX	1508/229	-	-	60	33	Yield at tape edge, failed in clamp
241	TENSOLITE	0/	60	210			Yield, no failure
241	TENSOLITE	838/200	50	330			Aging improves properties
241	TENSOLITE	1655/200	62	250			Aging improves properties
241	TENSOLITE	838/229	36	35			Aged at 229°C properties
241	TENSOLITE	1508/229	38	70			degraded

\- = FAILED WITHOUT YIELDING

N/mm^2 = NEWTONS PER SQUARE MILLIMETER

TABLE 9.4 - MECHANICAL TESTING OF AGED WIRE CONSTRUCTIONS (CONT.)

SPOOL REF.	INSULATION CONSTRUCTION	* AGED n/°C	YIELD STRESS (N/mm^2)	YIELD %	FAILURE STRESS (N/mm^2)	FAILURE STRAIN %	COMMENTS
242	TENSOLITE	0/	49	50	65	120	Yield, failed at clamp edge
242	TENSOLITE	838/220	32	70	35	10	Yield, skin bonds on surface
242	TENSOLITE	838/229	-	-	48	90	Yield, pock mark on surface
242	TENSOLITE	1508/229	45	55	44	60	Yield, fail at clamp
243	TENSOLITE	0/	-	-	72	139	All 243 samples yield,
243	TENSOLITE	838/200	-	-	50	65	failed at clamp edge
243	TENSOLITE	838/229	-	-	57	54	
243	TENSOLITE	1508/229	-	-	49	44	
201	M81381	0/	190	42	162	100	Failed at clamp
201	M81381	838/200	120	30	118	35	Multiple yield
201	M81381	838/229	110	25	110	25	Yield, sharp failure
201	M81381	1508/229	72	10	77	15	Yield, sharp failure
202	M81381	0/	150	55	135	65	Failed in clamp
202	M81381	838/200	138	25	122	70	Failed in clamp, yield, sharp failure
202	M81381	838/229	97	15	110	70	Yield, sharp failure
202	M81381	1508/229	90	10	100	61	Yield, sharp failure

- = FAILED WITHOUT YIELDING

N/mm^2 = NEWTONS PER SQUARE MILLIMETER

TABLE 9.4 - MECHANICAL TESTING OF AGED WIRE CONSTRUCTIONS (CONT.)

SPOOL REF.	INSULATION CONSTRUCTION	* AGED n/°C	YIELD STRESS (N/mm^2)	YIELD %	FAILURE STRESS (N/mm^2)	FAILURE STRAIN %	COMMENTS
203	M81381	0/	130	28	145	55	Outer jacket sharp failure
203	M81381	838/200	133	25	130	30	Yield, failed in clamp
203	M81381	838/229	133	25	130	30	Catastrophic failure
203	M81381	1508/229	114	23	107	25	Yield, failed at clamp
206	M22759	0/	-	-	38	66	Top layer failed at clamp
206	M22759	838/200	-	-	39	50	Discolored (tan) failed at clamp
206	M22759	838/229	-	-	36	64	Dark brown, failed at clamp, brittle
206	M22759	1508/229	-	-	30	52	Dark brown, catastrophic failure
207	M22759	0/	-	-	38	105	Yield, failed at clamp
207	M22759	838/200	-	-	37	61	Yield, failed in clamp
207	M22759	838/229	-	-	24	25	Discolored (brown), brittle, catastrophic failure
207	M22759	1508/229	-	-	22	39	Discolored (brown), brittle, catastrophic failure
208	M22759	0/	-	-	33	68	Catastrophic failure
208	M22759	838/200	-	-	40	78	Properties enhanced
208	M22759	838/229	-	-	25	56	Discolored (brown), catastrophic failure
208	M22759	1508/229	-	-	15	20	Discolored (brown), catastrophic failure

- = FAILED WITHOUT YIELDING

N/mm^2 = NEWTONS PER SQUARE MILLIMETER

TABLE 9.5 - SUMMARY OF AUGER PEAK HEIGHT DATA

Spool Ref.	Construction	Unaged 26 Gauge	Aged 220°C for 838 Hours 26 Gauge	Aged 220°C for 1,508 Hours 26 Gauge	Aged 220°C for 1,508 Hours 22 Gauge
136,138	Filtoex #135 - 22 Gauge #138 - 26 Gauge	C > F > #138 Ag > O > Cu > Cl After 6 min Sputter: Ag Cu/Ag = 0 Figures 46, 62	Ag > #138 Cl > C > O > F > Cu After 6 min Sputter: Ag Cu/Ag = 0 Figures 47, 63	Ag > #138 Cl > O > F After 6 min Sputter: Ag Cu/Ag = 0 Figures 48, 64	C > Cu > O > F > #136 Cl After 6 min Sputter: Cu = O > Ni > C Cu/Ni = 0.84 (See Note) Note: This Sample Had a Nickle Plate Rather Than Silver. Figures 49, 65
201,203	M81381 #201 - 22 Gauge #203 - 26 Gauge	C > Ag > #203 Cl After 6 min Sputter: Ag Cu/Ag = 0 Figures 50, 66	Ag > C > #203 Cl > O After 6 min Sputter: Ag Cu/Ag = 0 Figures 51, 67	Ag > C > #203 F > Cl > O > Cu After 6 min Sputter: Ag > F > Cu > O Cu/Ag = 0.111 Figures 52, 68	O > Cu > #201 Ag > C > Cl > F After 6 min Sputter: Cu = Ag Cu/Ag = 1.15 Figures 53, 69
206,208	M22759 #206 - 22 Gauge #208 - 26 Gauge	C > Ag > #208 O > (N or Cd) > Cl After 6 min Sputter: Ag > C Cu/Ag = 0 Note: N and Cd Auger Peaks Are Too Close to Tell Apart. Figures 54, 70	#208 Sb > Cu > O > Ag > (N or Cd) > C > Cl > F After 6 min Sputter: Ag > Cu > O > Sb Cu/Ag = 0.597 Note: Some Areas of the Surface Were Charging and Could Not Be Analyzed. Figures 55, 71	Cu > #208 C = (N or Cd) = O = F > Ag > Cl After 6 min Sputter: Ag > Cu > O > F Cu/Ag = 0.843 Figures 56, 72	Ag > Cu > O > C #206 Cl > Sb > F After 6 min Sputter: Ag > Cu > O > F Cu/Ag = 0.278 Figures 57, 73
241,243	Tensolite #241 - 22 Gauge #243 - 26 Gauge	C > Ag > #243 F > O > Cl > Cu After 6 min Sputter: Ag Cu/Ag = 0 Figures 58, 74	#243 Ag > C > F > O > Cu > Cl After 6 min Sputter: Ag > Cu O Cu/Ag = 0.153 Figures 59, 75	Ag > #243 O > Cu > F After 6 min Sputter: Ag > Cu = O Cu/Ag = 0.035 Figures 60, 76	Ag > O = Cu > #241 F After 6 min Sputter: Ag > Cu > O Cu/Ag = 0.444 Figures 61, 77

- The first line of elements listed for each sample/treatment indicates the larger peaks in the Auger spectrum for the unsputtered surface; smaller peaks are listed on the second line.
- Analysis after removal of about 600A of material by sputtering for 6 minutes is listed in the center of the box.
- The Cu/Ag ratio is the Auger peak height ratio for the 6 minute sputtered surface. Figure numbers in the lower right corner of each box refer to Auger and SEM data located in the Addendum.

Note: The Cu/Ni ratio has been adjusted to reflect published sensitivity factors for Ni and Ag so that it might be compared directly with the Cu/Ag ratios for other samples.

TABLE 9.6 - SUMMARY OF CHEMICAL COMPOUNDS EVOLVED FROM UNAGED AND AGED ELECTRICAL WIRE CONSTRUCTIONS

		UNAGED		AGED	
INSULATION CONSTRUCTION	SPOOL REF.	INITIAL HEAT 20 MINUTES AT 200°C	SECOND HEAT 20 MINUTES AT 300°C	INITIAL HEAT 20 MINUTES AT 200°C	SECOND HEAT 20 MINUTES AT 300°C
FILOTEX	136	L	M	M	M
	137	T	L	M	M
	138	L	T	L	M
TENSOLITE	241	T	T	T	T
	242	L	T	L	M
	243	M	M	T	M
M81381	201	T	M	-	-
	202	T	L	-	-
	203	L	T	T	T
M22759	206	T	T	T	M
	207	L	M	-	-
	208	M	M	T	M

L = LARGE AMOUNT OF VOLATILE COMPOUNDS DESORBED
M = MEDIUM AMOUNT OF VOLATILE COMPOUNDS DESORBED
T = TRACE AMOUNT OF VOLATILE COMPOUNDS DESORBED
- = NO MEASURABLE AMOUNT OF VOLATILE COMPOUNDS DESORBED

TABLE 9.7 - CHANGES OBSERVED IN THE PROPERTIES OF DIFFERENT ELECTRICAL WIRE CONSTRUCTIONS AFTER THERMO-OXIDATIVE AGING AS MEASURED BY DIFFERENT PHYSICAL-ANALYTICAL METHODS

Spool Ref.	Construction	Method		Stress/Strain	VGC/MS	Conductor Auger Spectrometry
		TGA	DSC			
136	Filotex	No Change	No Change	σ_f Reduced 37% ε_f Reduced 83%	Fluoro-Hydrocarbons and Alkylesters Evolved	Cu Diffuses Through Ni. Thin Layer
137	Filotex	No Change	No Change	σ_f Reduced 51% ε_f Reduced 65%		
138	Filotex	No Change	Slight Loss in Highest Melting Endotherm	σ_f Reduced 10% ε_f Reduced 37%	Aliphatic Hydrocarbons and Alkylesters Evolve	Trace Cu on Surface
241	Tensolite	No Change	No Change	σ_f Reduced 31% ε_f Reduced 62%		Cu on Surface and Interior After Aging
242	Tensolite	No Change	No Change	σ_f Reduced 27% ε_f Reduced 36%		
243	Tensolite	No Change	No Change	σ_f Reduced 32% ε_f Reduced 68%		Small Amount Cu on Surface
201	M81381	No Change	No Change	σ_f Reduced 52% ε_f Reduced 85%	Propyl- and Butyl-Benzenes Dimethyl Esters of Diboric Acids Evolve	Cu on Surface After Aging at 229°C
202	M81381	No Change	No Change	Little Change		
203	M81381	No Change	No Change	σ_f Reduced 26% ε_f Reduced 55%		
206	M22759	2 New Degradation Stability Reduced	Sharper Melting Endotherm	σ_f Reduced 21% ε_f Reduced 21%	Large Amounts of Fluoro-Hydrocarbons Are Released	Small Amount Cu on Surface After Aging
207	M22759	Stability Reduced. Weight Loss Begins - 310°C	More Perfect Crystals Formed	σ_f Reduced 42% ε_f Reduced 68%		
208	M22759	Stability Reduced, Begins to Lose Weight - 300°C	Crystalline Morphology, Changed, More Perfect Crystals	Short Term Aging σ_f Reduced 55% ε_f Reduced 70%		Large Amount Cu on Surface and Interior

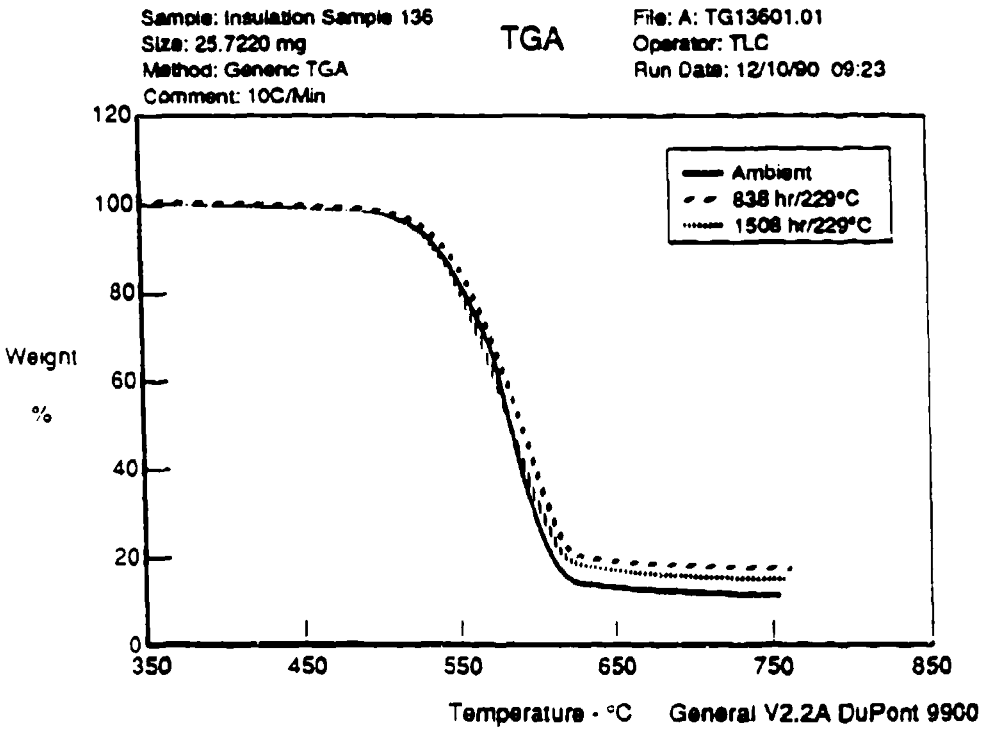

FIGURE 9.1 - THERMOGRAVIMETRIC ANALYSIS OF FILOTEX 136 CONSTRUCTION AS A FUNCTION OF THERMO-OXIDATIVE AGING

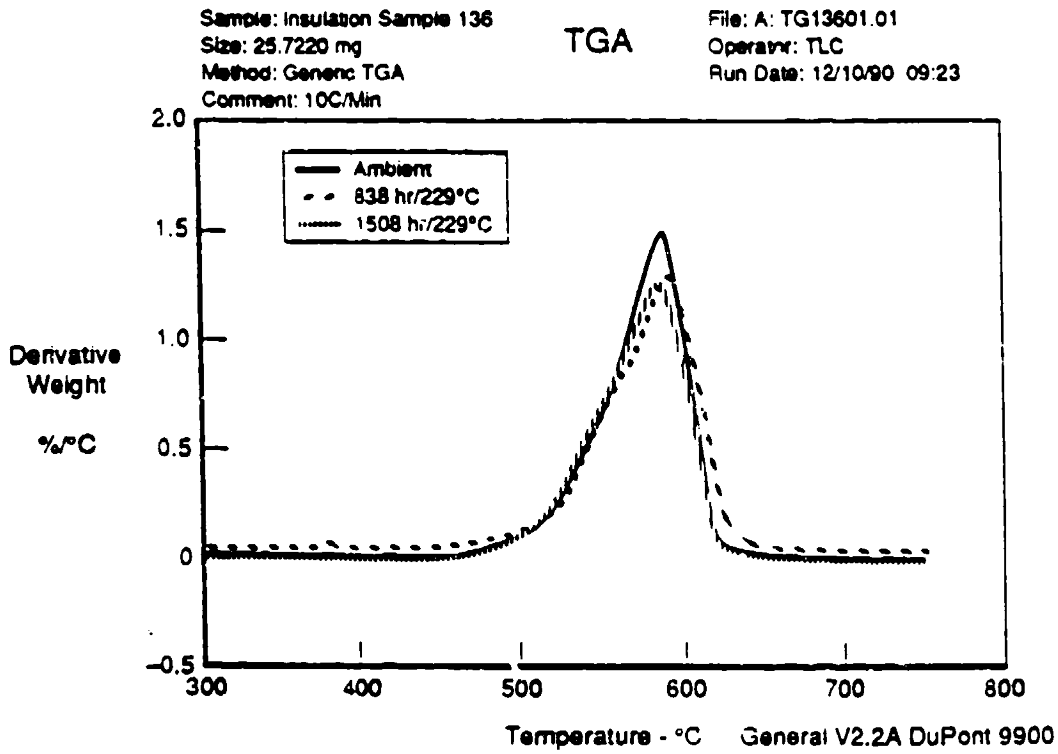

FIGURE 9.2 - THERMOGRAVIMETRIC ANALYSIS DERIVATIVE CURVES FROM FILOTEX 136 CONSTRUCTION AS A FUNCTION OF THERMO-OXIDATIVE AGING

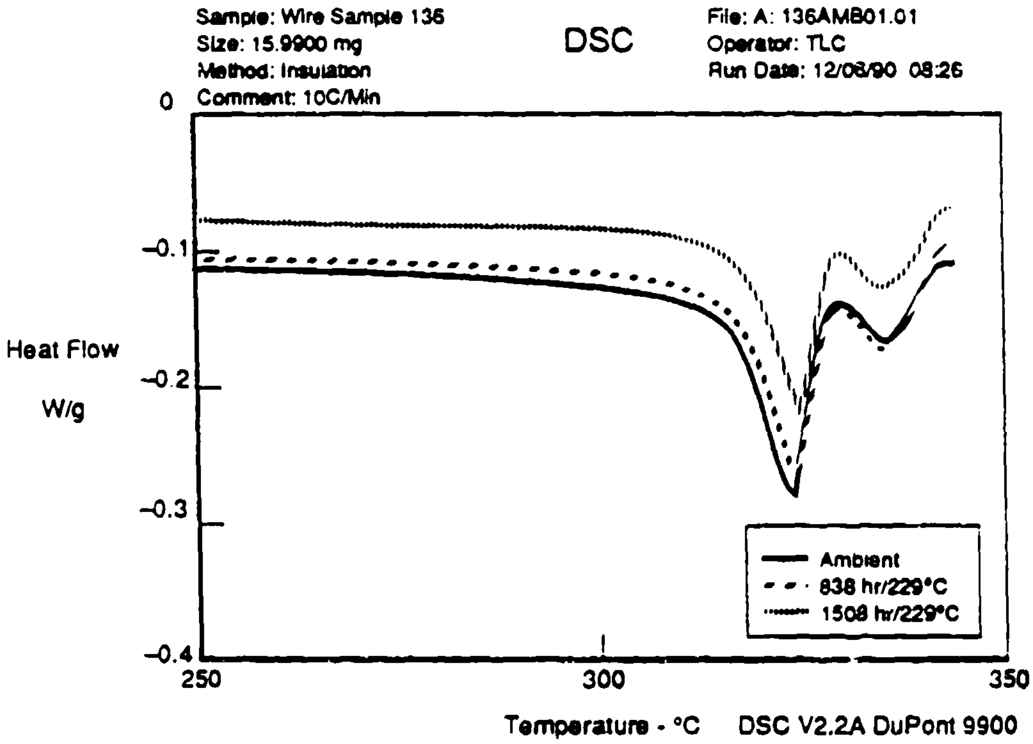

FIGURE 9.3 - DIFFERENTIAL SCANNING CALORIMETRIC ANALYSIS FOR FILOTEX 136 CONSTRUCTION AS A FUNCTION OF THERMAL AGING

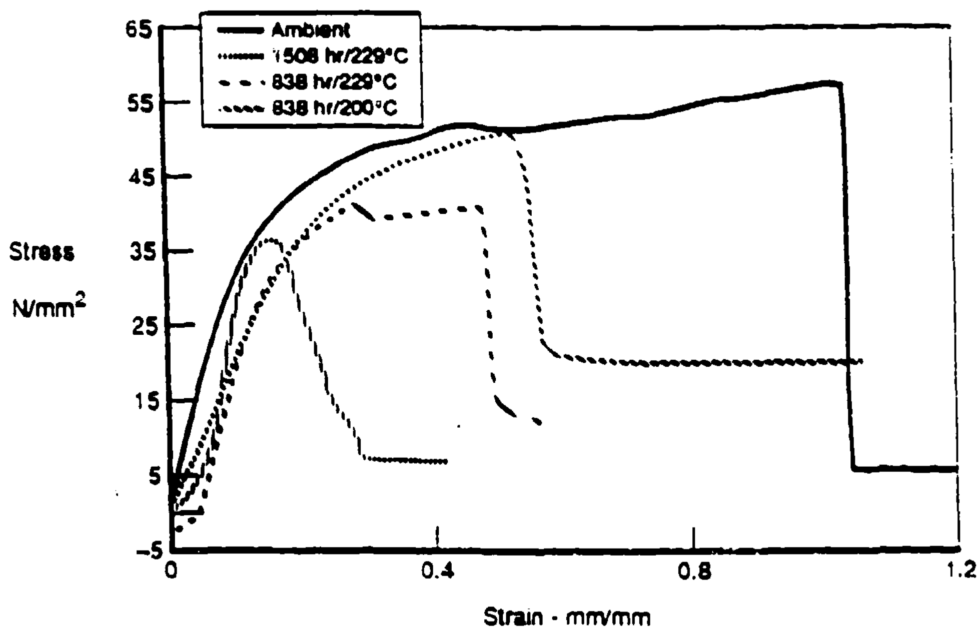

FIGURE 9.4 - MECHANICAL ANALYSIS (STRESS-STRAIN) OF UNAGED AND AGED FILOTEX 136 CONSTRUCTION

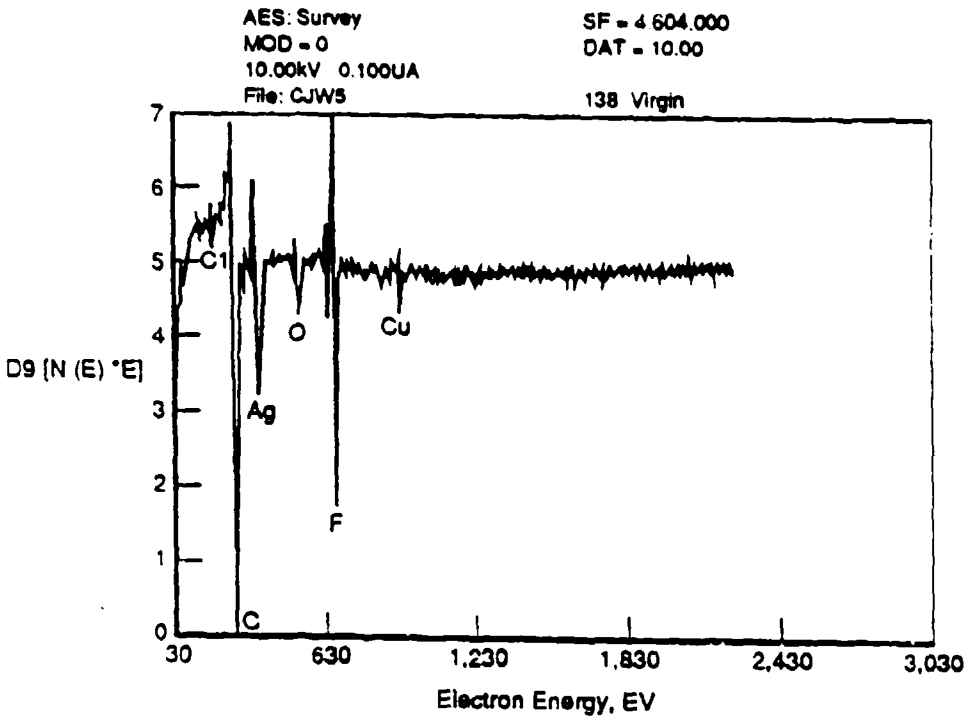

FIGURE 9.5 - AUGER SPECTRUM OF FILOTEX 138 UNAGED CONDUCTOR
A.) VIRGIN SURFACE

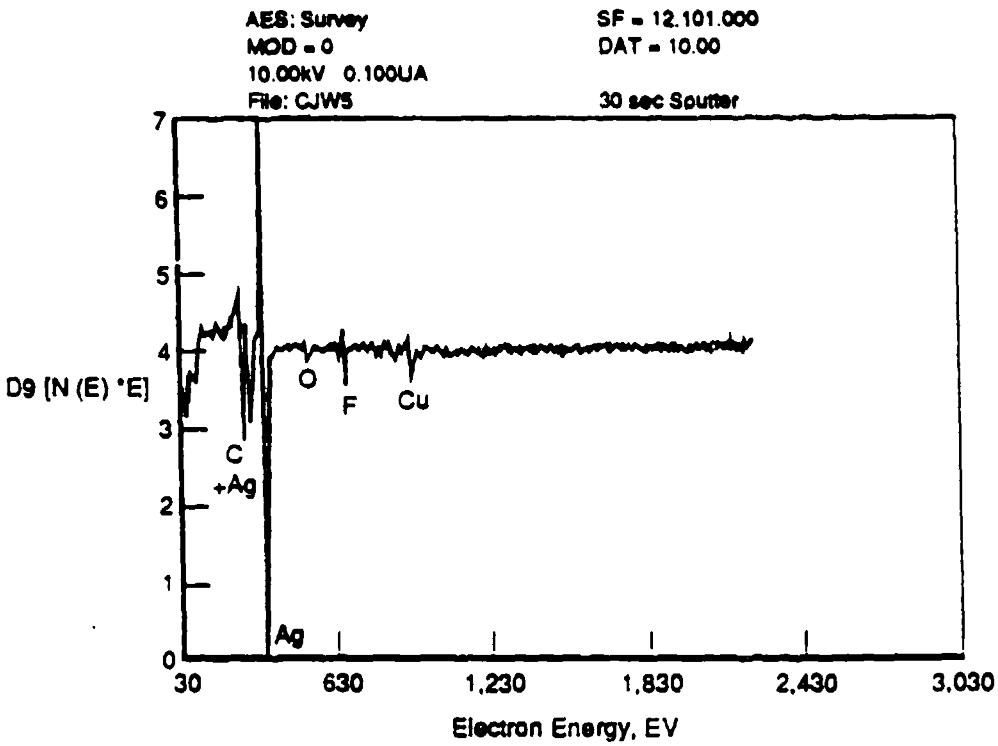

FIGURE 9.5 (CONT.) - AUGER SPECTRUM OF FILOTEX 138 UNAGED CONDUCTOR
B.) THIRTY SECOND SPUTTER

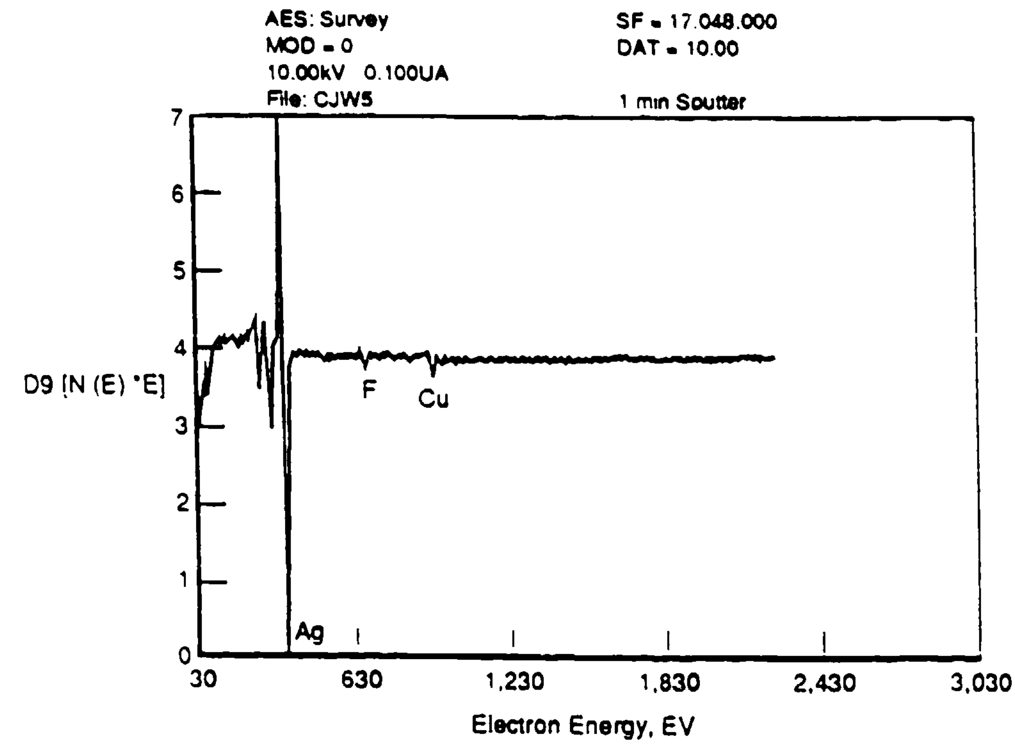

FIGURE 9.5 (CONT.) - AUGER SPECTRUM OF FILOTEX 138 UNAGED CONDUCTOR
C.) ONE MINUTE SPUTTER

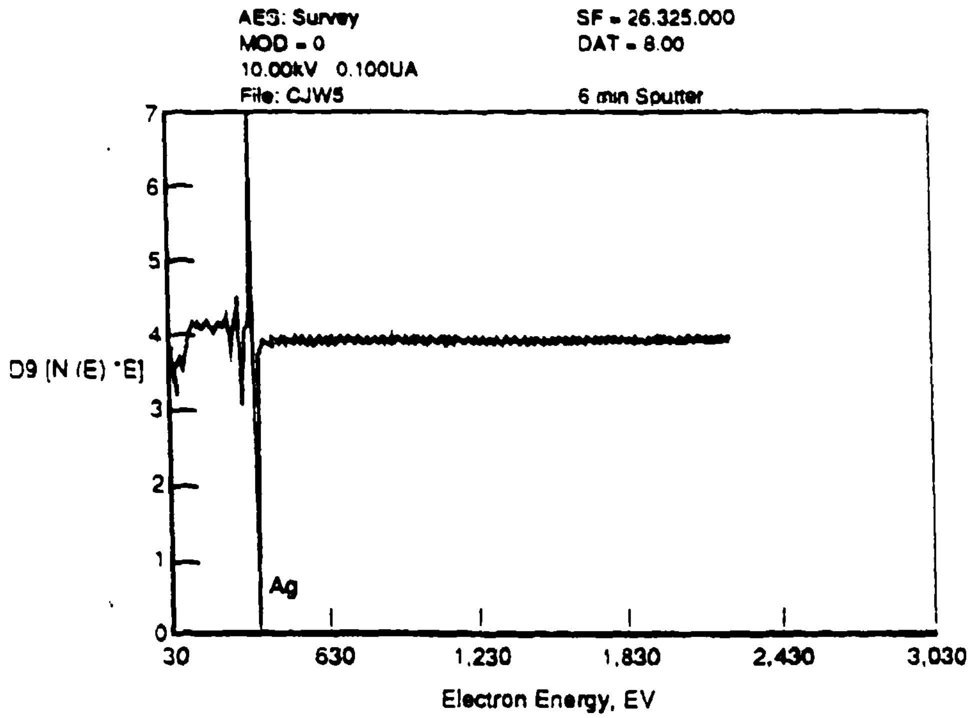

FIGURE 9.5 (CONT.) - AUGER SPECTRUM OF FILOTEX 138 UNAGED CONDUCTOR D.) SIX MINUTE SPUTTER

10.0 ROUND ROBIN TEST SUMMARY

1.0 SCOPE: The scope of the round robin evaluation was to choose tests from the MCAIR overall test program and request they be performed by other qualified sources to evaluate the repeatability/variability of the test results. Brand Rex, Champlain, Federal Aviation Technical Center, Filotex, Hudson International, Tensolite and Thermatics volunteered to participate in the round robin test program.

2.0 SAMPLES: Samples of 26 gauge, 5.8 mil thin wall (TN) hook up wire, 22 gauge, 5.8 mil thin wall (TN) hook up wire, 22 gauge, 8.6 mil thick wall (TK) airframe wire, 22 and 26A 2 conductor shielded and jacketed (SJ) cable were subjected to the round robin testing.

3.0 TEST EQUIPMENT: The test equipment specified in the SAE AS 4373 Test Procedure was required to be used by each round robin participant. Some participants did not have test equipment immediately available to conduct the required test and chose to omit one or more of the tests requested in round robin testing.

4.0 TEST PROCEDURES: Brand Rex, Champlain, Filotex, Tensolite and Thermatics were requested to conduct the following tests on the following samples:

Test Name	SAE AS 4373 Method #	Samples Tested	Special Requirements
Abrasion	701	22TK, 22TN Aged @ 200°C for 1000 hrs	RT @ 1, 2 & 3# Weights 150°C @ 1, 2 & 3# Weights
Dynamic Cut-Thru	703	22TK, 22TN, 26TN Aged @ 200°C for 1000 hrs	RT, 70, 150, 200°C
Flex Life	704	22TK, 22TN, 26TN 22-2SJ, 26A,2SJ Aged @ 200°C for 1000 hrs	
Notch Propagation	707	22TK, 22TN, 26TN Aged @ 200°C for 1000 hrs	
Time/Current to Smoke	507	22TK, 22TN, 26TN 22-2SJ, 26A-2SJ	
Flammability	801	22TK, 22TN, 22-2SJ	
Wire Fusing Time	511	22TK, 22TN, 26TN	
Insulation Tensile and Elongation	706	22TK, 22TN, 26TN	
Finished Diameter	901	22TK, 22TN, 26TN 22-2SJ, 26A-2SJ	
Finished Weight	902	22TK, 22TN, 26TN 22-2SJ, 26A-2SJ	

The Federal Aviation Technical Center was requested to conduct the following tests on the following samples:

Test Name	SAE AS 4373 Method #	Samples Tested
Smoke Quantity	803 (ASTM F 814)	22TK, 22TN, 26TN 22-2SJ, 26A-2SJ
Flammability	801	22TK, 22TN, 22-2SJ
Diameter	901	22TK, 22TN, 26TN 22-2SJ, 26A-2SJ
Weight	902	22TK, 22TN, 26TN 22-2SJ, 26A-2SJ

Information on the conductor properties was desirable. Although only one test source was solicited, it was felt this information would help complete the thoroughness of the total test evaluation conducted at MCAIR. Hudson International was requested to conduct the following conductor tests on the following samples:

Test Name	AS 4373 Method #	Samples Tested
Conductor Diameter	401	22TK, 22TN, 26TN
Conductor Tensile and Elongation	402/403	22TK, 22TN, 26TN
Conductor Resistance	404	22TK, 22TN, 26TN
Conductor Strand Blocking	405	22TK, 22TN, 26TN

5.0 OBSERVATIONS AND SUMMARY: None of the data generated from this round robin test program was incorporated into the statistical analysis. The data from all round robin testers was accumulated, MCAIR test data incorporated, and then tabularized in four forms.

TABLES RR1-8: Round Robin Tester Summary: Each table is a data summary extracted from each of the seven round robin testers and MCAIR (or DAC for Smoke Quantity and Time Current to Smoke) testing, showing first to last ranking based on test data.

TABLES RR9-25: Individual Test Summary: For each round robin test, the relative performance for each construction from every test source is shown.

TABLES RR26-36: Construction Ranking by Test: Records the ranking (1-6) of each construction for every test from each round robin tester and MCAIR (or DAC).

TABLE RR-37: Round Robin Average Ranking vs. MCAIR (DAC) Ranking: Identifies the average ranking (sum of rankings divided by number of round robin testers) of each construction in every test and compares it to the MCAIR ranking used in the statistical analysis.

5.1 Screening tests were performed at MCAIR on samples of wire and cable from the original production delivery from the candidate manufacturers. At the conclusion of the screening tests, it became necessary to procure a second quantity of wire and from the two baseline and four final candidate manufacturers. This biased the intent to use the round robin test data to evaluate the repeatability/variability of the round robin test data when compared to the MCAIR test data. The reader will observe in the RR1-25 tables, there are 100 and 200 series numbers. The 100 series are samples from the first procurement (tested by MCAIR) and the 200 series (tested by Round Robin Testers) are samples from the second procurement. It was expected to have some variation in materials and processing between 100 and 200 samples.

5.2 This is readily illustrated by the relative rankings shown in Tables RR-35 and 36 for finished diameter and weight. These differences are likely to be exhibited in other performance tests. It was also anticipated that equipment and techniques used by the different round robin testers would yield variations in test results. A careful study of the detail test data from each round robin tester shows significant variations in actual values. It can be further postulated that some of the SAE AS Test Methods are not sufficiently refined to achieve minimal variation between testers.

5.3 Several observations are noteworthy in the conductor testing performed by Hudson International. First, construction 208 (M22759/33-26), yielded tensile strength and DC resistance values that are representative of PD 135 cadmium chromium alloy instead of CS 95 beryllium copper alloy. All suppliers were requested to provide CS95 in 26AWG constructions. Second, construction 248 (26TN from Thermatics), exhibited significant sticking (adherence) of the insulation to the conductor strands. Strips where the conductor was free of insulation were not achievable during some conductor diameter, tensile and elongation tests. Third, constructions 243 (26TN from Tensolite) and 247 (22TN from Thermatics), exhibited significant strand blocking. An average of 7-8 out of 19 strands were countable. This may be due to over sintering the insulation tapes which resulted in blocked silver strands. Depending on the degree of blocked silver, the effect could be to stiffen the constructions.

5.4 The round robin test summary in Tables RR1-25 lists the candidates by ranking rather than by test value. This minimizes numerical difference and accentuates relative performance. This rationale was consistent with the overall program objective to determine the relative performance of the four candidates with respect to the baseline constructions.

Tables RR-9 through RR-25 list the relative ranking of each configuration of the two baseline and four candidate constructions for each round robin test. Tables RR26-36 provide a quick review of the relative rankings of constructions for each round robin test from each round robin tester and MCAIR (DAC). Since MCAIR used 100 construction samples to remain consistent between screening and full performance tests, and round robin testers used 200 series construction, a high degree of corroboration between the rankings was not expected.

5.5 It is concluded that the data from the round robin test program provides some corroboration to the test rankings between the round robin testers. There are exceptions to this conclusion and ranking in some tests by some testers could be challenged. SNK evaluations indicate the performance variations in many cases are not sufficiently different to statistically distinguish between candidates. Therefore, a shift of one or two positions in rank (based on data) may not mean a statistical difference in ranking.

5.6 Grateful acknowledgement of the excellent support and cooperation of the following people is made.

Kevin Coderre, Brand Rex

Rick Hawkins, Champlain

Pat Cahill, Federal Aviation Technical Center

Jean Pierre Ferlier, Filotex

Tom Eng, Hudson International

Don Dombrowsky, Tensolite

Bill Strickland, Thermatics

CODE NUMBER DESCRIPTION

F-33615-89-C-5605

Abbreviation Code
TK = THICK WALL
TN = THIN WALL
SJ = SHIELDED AND JACKETED
A = ALLOY CONDUCTOR
22 = 22 AWG CONDUCTOR
26 = 26 AWG CONDUCTOR
2 = 2 CONDUCTOR

CODE NO.	WIRE/CABLE TYPE
Primary Wire	
101/201	M81381/11-22
102/202	M81381/7-22
103/203	M81381/9-26
106/206	M22759/43-22
107/207	M22759/44-22
108/208	M22759/33-26
136/236	FILOTEX TK 22
137/237	FILOTEX TN 22
138/238	FILOTEX TN 26
141/241	TENSOLITE TK 22
142/242	TENSOLITE TN 22
143/243	TENSOLITE TN 26
146/246	THERMATICS TK 22
147/247	THERMATICS TN 22
148/248	THERMATICS TN 26
156/256	NEMA 3 TK 22
157/257	NEMA 3 TN 22
158/258	NEMA 3 TN 26
Shielded and Jacketed Cable	
104/204	M81381 22-2SJ
105/205	M81381 26A2SJ
109/209	M22759 22-2SJ
110/210	M22759 26A2SJ
139/239	FILOTEX 22-2SJ
140/240	FILOTEX 26A2SJ
144/244	TENSOLITE 22-2SJ
145/245	TENSOLITE 26A2SJ
149/249	THERMATICS 22-2SJ
150/250	THERMATICS 26A2SJ
159/259	NEMA 3 22-2SJ
160/260	NEMA 3 26A2SJ

ROUND ROBIN TESTER

TABLE RR-1A

ROUND [illegible]

CONSTRUCTION	ABRASION #701 (UNAGED) GREATEST # CYCLES 1ST 10-RT	20-RT	30-RT	ABRASION #701 (UNAGED) GREATEST # CYCLES 1ST 10-150C	20-150C	30-150C
22 THICK WALL	201 236 241 246 256 206	201 246 236 256 206 241	201 246 206 256 236 241	201 236 246 241 206 256ND	246 201 241 236 206 256ND	246 201 241 236 206 256ND
22 THIN WALL	202 237 242 247 207 257	202 237 207 247 242 257	202 237 207 247 242 257	202 237 247 242 257 207	202 247 237 242 257 207	202 242 207 237 247 257
26A THIN WALL	-	-	-	-	-	-
22 THIN 2 COND SHLD & JACK	-	-	-	-	-	-
26A THIN 2 COND SHLD & JACK	-	-	-	-	-	-

CONSTRUCTION	*ABRASION #701 (AGED) GREATEST # CYCLES 1ST 10-RT	20-RT	30-RT	*ABRASION #701 (AGED) GREATEST # CYCLES 1ST 10-150C	20-150C	30-150C
22 THICK WALL	201 236 241 246 256 206	246 201 236 206 256 241	246 201 206 236 241 256	201 236 246 241 256 206	246 201 236 241 256 206	246 201 241 236 206 256
22 THIN WALL	237 247 257 202 207 242	247 257 202 207 237 242	202 207 237 247 257 242	247 237 202 242 257 207	247 237 202 242 257 207	237 247 202 207 242 257
26A THIN WALL	-	-	-	-	-	-
22 THIN 2 COND SHLD & JACK	-	-	-	-	-	-
26A THIN 2 COND SHLD & JACK	-	-	-	-	-	-

CONSTRUCTION	DYNAMIC CUT THROUGH #703 (UNAGED) HIGHEST FORCE 1ST RT	70C	150C	200C	*DYNAMIC CUT THROUGH #703 (AGED) HIGHEST FORCE 1ST RT	70C	150C	200C
22 THICK WALL	201 256 246 206 236 241	201 246 256 241 236 206	201 246 256 241 236 206	201 246 256 241 236 206	201 241 256 246 206 236	201 241 256 246 236 206	201 241 246 256 236 206	201 241 246 236 256 206
22 THIN WALL	202 242 257 237 247 207	202 257 242 247 237 207	202 257 242 247 237 207	202 242 257 247 237 207	202 242 257 237 207 247	202 257 242 247 237 207	202 247 242 257 237 207	247 257 202 242 237 207
26A THIN WALL	203 248 258 238 243 208	203 238 258 243 248 208	203 238 243 248 258 208	203 248 243 238 258 208	203 248 243 258 208 238	203 248 243 208 258 238	243 248 203 238 258 208	243 203 248 238 258 208
22 THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-
26A THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-

{ THESE CONSTRUCTIONS HAD IDENTICAL NUMERICAL VALUES. THE LOWEST CONSTRUCTION NUMBER IS LISTED FIRST.
* SPECIMENS TESTED HAD BEEN SUBJECTED TO 1000 HOURS OF 200°C TEMPERATURE.
ND THIS CONSTRUCTION HAD NO DATA GENERATED AND WAS PLACED LAST. SEE RR TEST REPORT FOR DETAILS.

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ROUND ROBIN TESTER

TABLE RR-18

BRAND REX

CONSTRUCTION	*FLEX LIFE #704 HIGHEST # CYCLES 1ST UNAGED	*FLEX LIFE #704 HIGHEST # CYCLES 1ST HEAT AGED	NOTCH PROP #707 (UNAGED) HIGHEST # CYCLES 1ST 67%	NOTCH PROP #707 (UNAGED) HIGHEST # CYCLES 1ST 50%	*NOTCH PROP #707 (AGED) HIGHEST # CYCLES 1ST 67%	*NOTCH PROP #707 (AGED) HIGHEST # CYCLES 1ST 50%	TIME/CURRENT TO SMOKE #507 GREATEST I^2t 1ST	FLAMMABILITY #801 SHORTEST TIME 1ST	WIRE FUSING TIME #511 LONGEST TIME 1ST	INSULATION TENSILE STR & ELONG #706 GREATEST VAL 1ST TENS	INSULATION TENSILE STR & ELONG #706 GREATEST VAL 1ST ELONG	FINISHED DIAM #901 SMALLEST 1ST	FINISHED WEIGHT #902 SMALLEST 1ST
22 THICK WALL	201	201	206	201	241	201	201	201	201	201	241	236	201
	246	246	236	206	256	236	241	241	241	246	206	201	256
	256	241	241	236	236	241	246	246	236	256	256	256	246
	206	256	256	241	246	256	206	206	246	236	246	246	236
	236	236	246	246	201	246	236	236	206	206	236	206	206
	241	206	201	256	206	206	256	256	256	241	201	241	241
22 THIN WALL	257	202	242	202	242	242	202	247	242	202	242	202	202
	202	257	257	207	257	247	247	237	202	257	207	207	207
	237	242	247	237	237	257	242	242	237	237	247	237	237
	247	237	237	242	247	237	237	202	247	242	237	247	257
	242	247	202	247	202	202	207	207	207	207	202	257	247
	207	207	207	257	207	207	257	257	257	247	257	242	242
26A THIN WALL	203	258	238	203	243	238	203	-	243	203	208	208	203
	258	203	243	208	248	243	243	-	203	238	243	203	208
	238	238	248	238	258	248	248	-	208	258	238	248	248
	248	243	258	243	203	258	238	-	238	243	203	238	258
	243	248	203	248	238	203	208	-	248	208	258	258	238
	208	208	208	258	208	208	258	-	258	248ND	248ND	243	243
22 THIN 2 COND SHLD & JACK	244	239	-	-	-	-	244	204	-	-	-	204	204
	249	259	-	-	-	-	249	249	-	-	-	259	239
	259	209	-	-	-	-	239	259	-	-	-	209	259
	239	249	-	-	-	-	259	209	-	-	-	249	209
	209	244	-	-	-	-	209	244	-	-	-	239	249
	204	204	-	-	-	-	204	239	-	-	-	244	244
26A THIN 2 COND SHLD & JACK	245	240	-	-	-	-	210	-	-	-	-	250	205
	205	245	-	-	-	-	245	-	-	-	-	210	240
	260	250	-	-	-	-	205	-	-	-	-	240	210
	210	210	-	-	-	-	250	-	-	-	-	205	260
	240	260	-	-	-	-	240	-	-	-	-	245	250
	250	205	-	-	-	-	260	-	-	-	-	260	245

(THESE CONSTRUCTIONS HAD IDENTICAL NUMERICAL VALUES. THE LOWEST CONSTRUCTION NUMBER IS LISTED FIRST.
* SPECIMENS TESTED HAD BEEN SUBJECTED TO 1000 HOURS OF 200°C TEMPERATURE.
ND THIS CONSTRUCTION HAD NO DATA GENERATED AND WAS PLACED LAST. SEE RR TEST REPORT FOR DETAILS.

ROUND ROBIN TESTER

TABLE RR-2

CHAMPLAIN

CONSTRUCTION	*ABRASION #701 GREATEST # CYCLES 1ST 10-RT	20-RT	30-RT	*ABRASION #701 GREATEST # CYCLES 1ST 10-150C	20-150C	30-150C	*DYNAMIC CUT THROUGH #703 HIGHEST FORCE 1ST RT	70C	150C	200C	*FLEX LIFE #704 HIGHEST # CYCLES 1ST	*NOTCH PROP #707 HIGHEST # CYCLES 1ST 67%	50%	TIME/CURRENT TO SMOKE #507 GREATEST I^2t 1ST	FLAMMABILITY #801 SHORTEST TIME 1ST	WIRE FUSING TIME #511 LONGEST TIME AND HIGHEST CURRENT 1ST	INSULATION TENSILE STR & ELONG #706 GREATEST VAL 1ST TENS	ELONG	FINISHED DIAM #901 SMALLEST 1ST	FINISHED WEIGHT #902 SMALLEST 1ST
22 THICK WALL	246	246	246	{201	246	201	201	201	201	201	246	{236	{236**	241	246	241	201	241	236	201
	236	201	201	{236	201	246	256	246	246	246	201	{241	241**	201	201	201	246	206	201	256
	201	206	206	246	236	241	241	256	256	256	241	256	256**	246	241	246	236	236	246	{236
	241	256	256	241	241	236	206	241	241	241	236	246	201	206	256	206	256	201	256	{246
	256	236	236	256	256	256	246	236	236	236	256	201	246	256	236	236	241	256	206	206
	206	241	241	206	206	206	236	206	206	206	206	206	206	236	206	256	206	246	241	241
22 THIN WALL	247	247	202	237	247	247	202	202	202	202	202	{237	237**	202	202	242	202	242	202	202
	237	207	247	247	237	237	242	257	257	257	237	{242	242**	242	242	202	237	207	247	207
	202	237	237	202	202	242	257	247	247	247	257	257	257**	237	247	247	257	237	207	257
	257	257	207	242	242	202	207	242	242	242	242	247	202	257	237	257	242	202	237	237
	207	202	257	257	257	257	237	237	237	237	247	202	247	207	207	237	247	257	257	247
	242	242	242	207	207	207	247	207	207	207	207	207	207	247	257	207	207	247	242	242
26A THIN WALL	-	-	-	-	-	-	203	203	203	203	258	{203	203**	203	-	243	203	243	208	203
	-	-	-	-	-	-	208	248	243	248	203	{238	238**	243	-	203	238	248	203	208
	-	-	-	-	-	-	258	258	248	243	248	248	{243	248	-	248	243	208	238	248
	-	-	-	-	-	-	248	243	238	238	238	243	{248	238	-	208	248	238	248	258
	-	-	-	-	-	-	243	208	258	258	243	258	258	208	-	238	258	203	258	238
	-	-	-	-	-	-	238	238	208	208	208	208	208	258	-	258	208	258	243	243
22 THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-	-	-	244	-	-	244	249	-	-	-	204	204
	-	-	-	-	-	-	-	-	-	-	249	-	-	239	239	-	-	-	259	259
	-	-	-	-	-	-	-	-	-	-	239	-	-	249	204	-	-	-	209	239
	-	-	-	-	-	-	-	-	-	-	259	-	-	259	209	-	-	-	239	209
	-	-	-	-	-	-	-	-	-	-	209	-	-	209	259	-	-	-	249	249
	-	-	-	-	-	-	-	-	-	-	204	-	-	204	244	-	-	-	244	244
26A THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-	-	-	245	-	-	245	-	-	-	-	210	205
	-	-	-	-	-	-	-	-	-	-	240	-	-	240	-	-	-	-	240	240
	-	-	-	-	-	-	-	-	-	-	210	-	-	250	-	-	-	-	250	210
	-	-	-	-	-	-	-	-	-	-	250	-	-	210	-	-	-	-	205	260
	-	-	-	-	-	-	-	-	-	-	205	-	-	260	-	-	-	-	260	250
	-	-	-	-	-	-	-	-	-	-	260	-	-	205	-	-	-	-	245	245

{ THESE CONSTRUCTIONS HAD IDENTICAL NUMERICAL VALUES. THE LOWEST CONSTRUCTION NUMBER IS LISTED FIRST

* SPECIMENS TESTED HAD BEEN SUBJECTED TO 1000 HOURS OF 200°C TEMPERATURE

** 100% OF SPECIMENS PASSED DEEPEST NOTCH AND WERE NOT RETESTED.

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ROUND ROBIN TESTER

TABLE RR-3

FAA SAFETY CENTER

CONSTRUCTION	SMOKE QTY #803 SPEC. OPT. DEN. LOWEST VALUE 1ST	FLAMMABILITY #801 SHORTEST 1ST	DIAMETER #901 SMALLEST 1ST	WEIGHT #902 LOWEST 1ST
22 THICK WALL	201	246	236	201
	246	241	201	256
	241	201	246	246
	236	236	256	236
	256	256	206	206
	206	206	241	241
22 THIN WALL	202	242	202	202
	247	247	207	207
	242	202	237	237
	237	237	247	257
	257	207	257	247
	207	257	242	242
26A THIN WALL	243	-	208	203
	248	-	203	208
	203	-	248	248
	238	-	238	258
	208	-	258	238
	258		243	243
22 THIN, 2 COND SHLD & JACK	239	204	204	204
	249	259	209	259
	204	249	249	239
	244	239	259	209
	259	209	239	249
	209	244	244	244
26A THIN, 2 COND SHLD & JACK	240	-	250	205
	250	-	240	240
	205	-	205	210
	245	-	210	260
	210	-	245	250
	260	-	260	245

ROUND ROBIN TESTER

TABLE RR-4

FILOTEX

	*ABRASION #701 (AGED) GREATEST # CYCLES 1ST			*ABRASION #701 (AGED) GREATEST # CYCLES 1ST			*DYNAMIC CUT THROUGH #703 (AGED) HIGHEST FORCE 1ST				*FLEX LIFE #704 (AGED) HIGHEST # CYCLES 1ST	*NOTCH PROP #707 (AGED) HIGHEST # CYCLES 1ST		TIME/CURRENT TO SMOKE #507 GREATEST I²t 1ST	FLAMMABILITY #801 SHORTEST TIME 1ST	WIRE FUSING TIME #511 & ELONG #706 LONGEST TIME 1ST	INSULATION TENSILE STR GREATEST 1ST		FINISHED DIAM #901 SMALLEST 1ST	FINISHED WEIGHT #902 SMALLEST 1ST
CONSTRUCTION	10-RT	20-RT	30-RT	10-150C	20-150C	30-150C	RT	70C	150C	200C		673	505				TENS	ELONG		
22 THICK WALL	(201	246	246	(201	246	246	-	-	-	-	201	236	256	-	201	-	201	241	201	206
	246	236	201	246	201	201	-	-	-	-	236	256	236	-	241	-	246	206	236	201
	236	256	206	236	236	241	-	-	-	-	246	241	241	-	236	-	236	236	246	256
	241	201	236	241	241	236	-	-	-	-	256	246	201	-	246	-	256	246	256	246
	256	241	241	256	206	(206	-	-	-	-	241	201	206	-	206	-	241	256	206	236
	206	206	256	206	256	256	-	-	-	-	206	206	246	-	256	-	206	201	241	241
22 THIN WALL	247	247	202	247	247	247	-	-	-	-	202	257	242	-	242	-	202	207	202	202
	237	237	237	237	237	242	-	-	-	-	237	237	257	-	247	-	237	242	(207	207
	242	207	247	242	242	237	-	-	-	-	257	242	237	-	202	-	247	237	247	257
	207	202	207	202	202	202	-	-	-	-	247	202	202	-	237	-	257	202	237	247
	257	257	242	257	257	257	-	-	-	-	242	207	247	-	257	-	242	247	257	237
	202	242	257	207	207	207	-	-	-	-	207	247	207	-	207	-	207	257	242	242
26A THIN WALL	-	-	-	-	-	-	-	-	-	-	203	238	(203	-	-	-	203	208	208	203
	-	-	-	-	-	-	-	-	-	-	258	243	(238	-	-	-	238	238	203	208
	-	-	-	-	-	-	-	-	-	-	238	248	243	-	-	-	258	243	248	248
	-	-	-	-	-	-	-	-	-	-	248	203	248	-	-	-	248	203	238	238
	-	-	-	-	-	-	-	-	-	-	243	258	258	-	-	-	243	258	258	258
	-	-	-	-	-	-	-	-	-	-	208	208	208	-	-	-	208	248	243	243
22 THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	249	-	-	-	204	204
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	204	-	-	-	209	239
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	239	-	-	-	249	259
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	244	-	-	-	(239	209
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	209	-	-	-	259	249
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	259	-	-	-	244	244
26A THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	210	[illegible]
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	250	240
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	240	210
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	205	260
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	260	250
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	245	205

(THESE CONSTRUCTIONS HAD IDENTICAL NUMERICAL VALUES. THE LOWEST CONSTRUCTION NUMBER IS LISTED FIRST
* SPECIMENS TESTED HAD BEEN SUBJECTED TO 1000 HOURS OF 200°C TEMPERATURE

ROUND ROBIN TESTER

TABLE RR-5

HUDSON INTERNATIONAL

CONSTRUCTION	CONDUCTOR DIAMETER #401	CONDUCTOR TENSILE LBS #402/403	CONDUCTOR ELONG % #402/403	CONDUCTOR RESISTANCE #404	CONDUCTOR STRAND BLOCKING #405
	SMALLEST 1ST	LARGEST 1ST	LARGEST 1ST	LOWEST 1ST	HIGHEST # OF INDIVID STRANDS 1ST
22 THICK WALL	236	(201	241	246	(201
	201	206	236	206	206
	206	246	206	(236	(241
	256	256	246	256	246
	241	236	201	241	256
	246	241	256	201	236
22 THIN WALL	237	257	247	247	(207
	207	247	202	202	257
	257	(202	242	242	242
	242	237	207	257	202
	202	242	257	237	237
	247	207	237	207	247
26 THIN WALL	208	203	238	208'	248
	203	258	258	238	208
	(238	(238	203	248	258
	258	243	243	243	203
	243	248	208	258	238
	248	208'	248''	203	243

(THESE CONSTRUCTIONS HAD IDENTICAL NUMERICAL VALUES. THE LOWEST CONSTRUCTION NUMBER IS LISTED FIRST
' MEASUREMENTS SUGGEST 26 ALLOY IS PD135 INSTEAD OF CS95
'' INSULATION RESIDUE REMAINING ON CONDUCTOR MAY HAVE AFFECTED MEASURED VALUES.

ROUND ROBIN TESTER

TABLE RR-6A

MCA18

CONSTRUCTION	ABRASION #701 (UNAGED) GREATEST # CYCLES 1ST			ABRASION #701 (UNAGED) GREATEST # CYCLES 1ST			*ABRASION #701 (AGED) GREATEST # CYCLES 1ST			*ABRASION #701 (AGED) GREATEST # CYCLES 1ST			DYNAMIC CUT THROUGH #703 (UNAGED) HIGHEST FORCE 1ST				*DYNAMIC CUT THROUGH #703 (AGED) HIGHEST FORCE 1ST			
	10-RT	20-RT	30-RT	10-150C	20-150C	30-150C	10-RT	20-RT	30-6T	10-150C	20-150C	30-150C	RT	70C	150C	200C	RT	70C	150C	200C
22 THICK WALL	101	101	101	101	146	146	136	136	136	146	146	146	101	101	101	101	101	101	101	101
	146	146	146	141	101	101	146	146	146	101	136	101	106	106	156	146	156	156	156	146
	136	136	136	146	141	141	106	101	101	141	101	136	156	146	146	156	106	146	141	141
	141	106	106	136	136	136	101	106	106	136	141	141	146	156	141	141	141	141	146	156
	156	156	156	156	156	156	141	156	156	156	156	156	136	141	136	136	146	106	136	136
	106	141	141	106	106	106	156	141	141	106	106	106	141	136	106	106	136	136	106	106
22 THIN WALL	137	137	137	142	{ 142	142	137	137	137	147	147	147	102	102	102	102	102	102	102	102
	147	102	102	102	147	102	147	102	147	137	137	142	157	142	157	157	157	157	157	142
	102	147	147	147	102	147	107	147	102	142	142	{ 102	137	137	147	147	142	142	142	157
	142	107	157	137	137	{ 137	102	107	107	102	102	137	147	157	142	142	147	147	147	147
	157	157	{ 107	157	157	157	142	157	157	107	157	157	107	147	137	137	107	137	137	137
	107	142	142	107	107	107	157	142	142	157	107	107	142	107	107	107	137	107	107	107
26A THIN WALL	.	.	.	.	.	.	.	.	.	.	.	.	103	103	103	103	103	103	103	103
	.	.	.	.	.	.	.	.	.	.	.	.	108	143	148	138	158	148	143	143
	.	.	.	.	.	.	.	.	.	.	.	.	138	138	{ 138	148	108	143	138	138
	.	.	.	.	.	.	.	.	.	.	.	.	148	108	143	143	148	158	148	148
	.	.	.	.	.	.	.	.	.	.	.	.	158	148	158	158	143	138	158	158
	.	.	.	.	.	.	.	.	.	.	.	.	143	158	108	108	138	108	108	108
22 THIN 2 COND SHLD & JACK	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
26A THIN 2 COND SHLD & JACK	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

{ THESE CONSTRUCTIONS HAD IDENTICAL NUMERICAL VALUES. THE LOWEST CONSTRUCTION NUMBER IS LISTED FIRST

* SPECIMENS TESTED HAD BEEN SUBJECTED TO 1000 HOURS OF 200°C TEMPERATURE.

F-33615-89-C-5605

ROUND ROBIN TESTER

TABLE RR-6B

NEAIR

CONSTRUCTION	FLEX LIFE #704 (UNAGED) HIGHEST # CYCLES 1ST	*FLEX LIFE #704 (AGED) HIGHEST # CYCLES 1ST	NOTCH PROP #707 (UNAGED) HIGHEST # CYCLES 1ST 67%	50%	*NOTCH PROP #707 (AGED) HIGHEST # CYCLES 1ST 67%	50%	TIME/CURRENT TO SMOKE #507 OAC GREATEST I^2t 1ST	FLAMMABILITY #801 SHORTEST TIME 1ST	WIRE FUSING TIME #511 LONGEST TIME 1ST	INSULATION TENSILE STR & ELONG #706 GREATEST VAL 1ST (2 IN/MIN) TENS	ELONG	FINISHED TAW #901 SMALLEST 1ST	FINISHED WEIT IT #90[illegible] SMALLEST 1ST
22 THICK WALL	101	101	101	NO	101	101**	101	101	141	101	141	136	101
	156	146	106	TEST	136	136**	141	141	101	146	106	146	136
	141	156	136	DATA	141	141**	146	146	146	156	146	156	156
	106	141	141	-	146	146**	136	136	156	236	156	101	146
	136	136	146	-	156	156**	156	156	106	141	236	141	106
	146	106	156	-	106	106	106	106	136	106	101	106	141
22 THIN WALL	102	102	102	-	102	102**	102	142	142	102	142	137	137
	157	157	107	-	137	137**	147	102	102	147	107	107	157
	142	147	137	-	142	142**	137	137	147	237	147	147	102
	137	137	142	-	147	147**	142	147	157	142	237	102	107
	107	142	147	-	157	157**	157	157	107	157	102	157	147
	107	107	157	-	107	107	107	107	137	107	157	142	142
26A THIN WALL	103	158	103	-	103	103**	103	-	103	-	-	138	103
	158	103	108	-	138	138**	138	-	143	-	-	103	108
	148	148	138	-	143	143*	148	-	138	-	-	148	138
	108	143	143	-	148	148**	143	-	148	-	-	108	158
	143	108	148	-	158	158**	158	-	108	-	-	158	148
	138	138	158	-	108	108	108	-	158	-	-	143	143
22 THIN 2 COND SHLD & JACK	144	-	-	-	-	-	149	144	-	-	-	109	104
	239	-	-	-	-	-	159	149	-	-	-	104	159
	159	-	-	-	-	-	139	104	-	-	-	159	109
	109	-	-	-	-	-	104	109	-	-	-	239	239
	149	-	-	-	-	-	144	159	-	-	-	149	149
	104	-	-	-	-	-	109	139ND	-	-	-	144	144
26A THIN 2 COND SHLD & JACK	145	-	-	-	-	-	140	-	-	-	-	110	105
	160	-	-	-	-	-	150	-	-	-	-	150	240
	150	-	-	-	-	-	145	-	-	-	-	105	150
	240	-	-	-	-	-	105	-	-	-	-	240	110
	110	-	-	-	-	-	110	-	-	-	-	145	160
	105	-	-	-	-	-	160	-	-	-	-	160	145

(THESE CONSTRUCTIONS HAD IDENTICAL NUMERICAL VALUES. THE LOWEST CONSTRUCTION NUMBER IS LISTED FIRST.
* SPECIMENS TESTED HAD BEEN SUBJECTED TO 1000 HOURS OF 200°C TEMPERATURE.
ND THIS CONSTRUCTION HAD NO DATA GENERATED AND WAS PLACED LAST. SEE RR TEST REPORT FOR EXPLANATION.
** 100% OF SPECIMENS PASSED DEEPEST NOTCH AND WERE NOT RETESTED.

F-33615-89-C-5605

ROUND ROBIN TESTER

TABLE RR-7

TENSOLITE

CONSTRUCTION	*ABRASION #701 GR. TEST # CYCLES 1ST 10-87	20-81	30-81	*ABRASION #701 GREATEST # CYCLES 1ST 10-150C	20-150C	30-150C	*DYNAMIC CUT THROUGH #703 HIGHEST FORCE 1ST 81	[illegible]C	150C	200C	*FLEX LIFE #704 HIGHEST # CYCLES 1ST	*NOTCH PROP #707 HIGHEST # CYCLES 1ST 67%	50%	TIME/CURRENT TO SMOKE #507 GREATEST I^2t 1ST	FLAMMABILITY #801 SHORTEST TIME 1ST	WIRE FUSING TIME #511 LONGEST TIME 1ST	INSULATION TENSILE STR & ELONG #706 GREATEST VAL 1ST TENS	ELONG	FINISHED DIAM #901 SMALLEST 1ST	FINISHED WEIGHT #902 SMALLEST 1ST
22 THICK WALL	246 201 236 241 206 256	246 206 201 256 241 236	206 246 201 236 241 256	NO TEST DATA	-	-	201 206 256 241 246 236	201 246 256 241 236 206	201 246 241 256 236 206	201 246 241 256 236 206	201 246 236 256 241 206	241 201 246 (206 256 236	(241 256 236 246 201 206	NO TEST DATA	241 246 201 236 206 [illegible]	NO TEST DATA	201 246 256 236 241 206	241 206 201 246 236 256	236 201 246 256 206 241	201 256 246 236 206 241
22 THIN WALL	247 237 242 202 207 257	247 237 207 257 202 242	202 237 247 207 257 242	-	-	-	202 242 257 207 237 247	[illegible] [illegible] 242 247 237 207	202 247 (237 242 257 207	242 202 247 257 237 207	202 237 257 202 247 207	242 247 237 207 (202 257	242 237 247 257 202 207	-	247 242 202 237 207 257	-	202 237 242 257 247 207	242 207 237 247 202 257	207 247 202 237 257 242	202 207 257 (237 247 242
26A THIN WALL	-	-	-	-	-	-	203 208 258 243 248 238	203 248 243 238 258 206	203 248 243 238 258 208	203 248 243 238 258 208	258 203 238 248 243 208	(238 243 258 248 203 208	(203 238 243 248 258 208	-	-	-	203 243 238 258 248 208	243 248 208 238 203 258	208 203 238 248 258 243	203 208 248 258 238 243
22 THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	209 249 239 204 244 259	-	-	-	204 209 249 259 239 244	204 239 259 209 249 244
26A THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	250 240 210 205 245 260	205 240 210 260 250 245

(THESE CONSTRUCTIONS HAD IDENTICAL NUMERICAL VALUES. THE LOWEST CONSTRUCTION NUMBER IS LISTED FIRST.

* SPECIMENS TESTED HAD BEEN SUBJECTED TO 1000 HOURS OF 200°C TEMPERATURE.

F-33615-89-C-5605

ROUND ROBIN TESTER

TABLE RR-8

THERMALICS

CONSTRUCTION	*ABRASION #701 GREATEST # CYCLES 1ST 10-RT	20-RT	30-RT	*ABRASION #701 GREATEST # CYCLES 1ST 10-150C	20-150C	30-150C	*DYNAMIC CUT THROUGH #703 HIGHEST FORCE 1ST RT	70C	150C	200C	*FLEX LIFE #704 HIGHEST # CYCLES 1ST	*NOTCH PROP #707 HIGHEST # CYCLES 1ST 67%	50%	TIME/CURRENT TO SMOKE #507 GREATEST I^2t 1ST	FLAMMABILITY #801 SHORTEST TIME 1ST	WIRE FUSING TIME #511 LONGEST TIME 1ST	INSULATION TENSILE STR & ELONG #706 GREATEST VAL 1ST TENS	ELONG	FINISHED DIAM #901 SMALLEST 1ST	FINISHED WEIGHT #902 SMALLEST 1ST
22 THICK WALL	246	246	246	246	246	246	201	201	201	246	201	236	236	241	246	236	201	241	201	201
	241	201	201	201	201	201	256	246	246	241	246	241	241	201	241	241	246	236	246	256
	201	206	206	236	236	241	241	256	256	256	256	256	256	246	201	201	236	206	236	246
	236	241	236	241	241	236	206	236	241	236	241	201	201	256	236	246	256	246	256	236
	206	236	241	256	256	256	246	206	236	206	206	246	246	236	256	206	241	256	206	206
	256	256	256	206	206	206	236	241ND	206	201ND	236	206	206	206	206	256	206	201	241	241
22 THIN WALL	247	247	202	247	247	247	202	202	202	202	202	242	237	247	202	207	202	207	242	202
	237	207	247	237	237	242	242	257	247	247	257	257	242	242	242	237	237	242	202	207
	207	237	237	242	242	237	257	242	257	257	237	237	257	202	237	242	242	237	247	257
	202	202	207	202	202	202	207	237	242	237	242	247	247	257	247	247	257	202	237	237
	257	257	242	257	257	257	237	247	237	207ND	247	207	202	237	257	202	247	247	207	247
	242	242	257	207	207	207	247	207	207	242ND	207	202	207	207	207	257	207	257	257	242
26A THIN WALL	258	258	203	248	248	203	203	203	203	203	258	203	203	243	-	203	203	243	208	203
	248	248	248	238	243	248	208	243	248	248	203	238	238	203	-	243	243	208	203	208
	208	203	243	243	238	243	248	248	243	243	248	243	243	238	-	238	238	238	248	248
	243	208	238	203	203	238	258	258	238	238	238	258	258	248	-	248	258	258	238	258
	203	238	208	258	258	208	243	238	258	258	243	248	248	258	-	258	208	203	258	238
	238	243	258	208	208	258	238	208	208	208	208	208	208	208	-	208	248ND	248ND	243	243
22 THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-	-	-	249	-	-	244	249	-	239	209	204	204
	-	-	-	-	-	-	-	-	-	-	244	-	-	209	259	-	204	244	249	239
	-	-	-	-	-	-	-	-	-	-	209	-	-	259	204	-	249	249	259	259
	-	-	-	-	-	-	-	-	-	-	239	-	-	204	239	-	259	204	209	209
	-	-	-	-	-	-	-	-	-	-	204	-	-	239	209	-	209	259	239	249
	-	-	-	-	-	-	-	-	-	-	259	-	-	249	244	-	244	239	244	244
26A THIN 2 COND SHLD & JACK	-	-	-	-	-	-	-	-	-	-	-	-	-	240	-	-	205	245	240	205
	-	-	-	-	-	-	-	-	-	-	-	-	-	210	-	-	240	210	210	240
	-	-	-	-	-	-	-	-	-	-	-	-	-	245	-	-	250	250	205	210
	-	-	-	-	-	-	-	-	-	-	-	-	-	250	-	-	260	240	250	260
	-	-	-	-	-	-	-	-	-	-	-	-	-	205	-	-	210	205	245	250
	-	-	-	-	-	-	-	-	-	-	-	-	-	260	-	-	245	260	260	245

{ THESE CONSTRUCTIONS HAD IDENTICAL NUMERICAL VALUES. THE LOWEST CONSTRUCTION NUMBER IS LISTED FIRST.

* SPECIMENS TESTED HAD BEEN SUBJECTED TO 1000 HOURS OF 200°C TEMPERATURE

ND THIS CONSTRUCTION HAD NO DATA GENERATED AND WAS PLACED LAST. SEE RR TEST REPORT FOR EXPLANATION.

TABLE RR-9

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: ABRASION AFTER 1000 HOURS @ 200°C
TEST SPECIMEN: 22TK

TEST PARAMETER	BRAND REX UNAGED	BRAND REX AGED	CHAMPLAIN AGED	FILOTEX AGED	MCAIR UNAGED	MCAIR AGED	TENSOLITE AGED	THERMATICS AGED
1# Wt., Room Temp.	(201	(201	246	(201	101	136	246	246
	(236	(236	236	246	146	146	201	241
	(241	(241	201	236	136	106	236	201
	(246	(246	241	241	141	101	241	236
	256	256	256	256	156	141	206	206
	206	206	206	206	106	156	256	256
2# Wt., Room Temp.	(201	246	246	246	101	136	246	246
	246	201	201	236	146	146	206	201
	236	236	206	256	136	101	201	206
	256	206	256	201	106	106	256	241
	206	256	236	241	156	156	241	236
	241	241	241	206	141	141	236	256
3# Wt., Room Temp.	201	246	246	246	101	136	206	246
	246	201	201	201	146	146	246	201
	206	206	206	206	136	101	201	206
	256	236	256	236	106	106	236	236
	236	241	236	241	156	156	241	241
	241	256	241	256	141	141	256	256

(These constructions had identical numerical values. The lowest construction number is listed first.)

TABLE RR-10

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: ABRASION AFTER 1000 HOURS @ 200°C
TEST SPECIMEN: 22TK

TEST PARAMETER	RANKING BY SOURCE: BRAND REX UNAGED	BRAND REX AGED	CHAMPLAIN AGED	FILOTEX AGED	MCAIR UNAGED	MCAIR AGED	TENSOLITE	THERMATICS AGED
1# Wt., 150°C	(201	(201	(201	(201	101	146	NO TEST DATA	246
	(236	(236	(236	246	141	101		201
	246	246	246	236	146	141		236
	241	241	241	241	136	136		241
	206	256	256	256	156	156		256
	256ND	206	206	206	106	106		206
2# Wt., 150°C	246	246	246	246	146	146		246
	201	201	201	201	101	136		201
	241	236	236	236	141	101		236
	236	241	241	241	136	141		241
	206	256	256	206	156	156		256
	256ND	206	206	256	106	106		206
3# Wt., 150°C	246	246	201	246	146	146		246
	201	201	246	201	101	101		201
	241	241	241	241	141	136		241
	236	236	236	236	136	141		236
	206	(206	256	(206	156	156		256
	256ND	256	206	256	106	106		206

(These constructions had identical numerical values. The lowest construction number is listed first.)
ND No Data

TABLE RR-11

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: ABRASION AFTER 1000 HOURS @ 200°C
TEST SPECIMEN: 22TN

TEST PARAMETER	RANKING BY SOURCE							
	BRAND REX		CHAMPLAIN	FILOTEX	MCAIR		TENSOLITE	THERMATICS
	UNAGED	AGED	AGED	AGED	UNAGED	AGED	AGED	AGED
1# Wt., Room Temp.	202	(237	247	247	137	137	247	247
	237	247	237	237	147	147	237	237
	242	257	202	242	102	107	242	207
	247	202	257	207	142	102	202	202
	207	207	207	257	157	142	207	257
	257	242	242	202	107	157	257	242
2# Wt., Room Temp.	202	247	247	247	137	137	247	247
	237	257	207	237	102	102	237	207
	207	202	237	207	147	147	207	237
	247	(207	257	202	107	107	257	202
	242	237	202	257	157	157	202	257
	257	242	242	242	142	142	242	242
3# Wt., Room Temp.	202	202	202	202	137	137	202	(202
	237	207	247	237	102	147	237	247
	207	(237	237	247	147	102	247	237
	247	247	207	207	157	107	207	207
	242	257	257	242	(107	157	257	242
	257	242	242	257	142	142	242	257

(These constructions had identical numerical values. The lowest construction number is listed first.)

TABLE RR-12

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: ABRASION AFTER 1000 HOURS @ 200°C
TEST SPECIMEN: 22TN

TEST PARAMETER	RANKING BY SOURCE: BRAND REX UNAGED	BRAND REX AGED	CHAMPLAIN AGED	FILOTEX AGED	MCAIR UNAGED	MCAIR AGED	TENSOLITE	THERMATICS AGED
1# Wt., 150°C	202	247	237	247	142	147	NO TEST DATA	247
	237	237	247	237	102	137		237
	247	202	202	242	147	142		242
	242	242	242	202	137	102		202
	257	257	257	257	157	107		257
	207	207	207	207	107	157		207
2# Wt., 150°C	202	247	247	247	(142	147		247
	247	237	237	237	147	137		237
	237	202	202	242	102	142		242
	242	242	242	202	137	102		202
	257	257	(257	257	157	157		257
	207	207	207	207	107	107		207
3# Wt., 150°C	202	(237	247	247	142	147		247
	242	247	237	242	102	142		242
	(207	(202	242	237	147	(102		237
	(237	(207	202	202	(137	137		202
	(247	(242	257	257	157	157		257
	257	257	207	207	107	107		207

(These constructions had identical numerical values. The lowest construction number is listed first.)

TABLE RR-13

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: DYNAMIC CUT THRU AFTER 1000 HRS @ 200°C
TEST SPECIMEN: 22TK

TEST PARAMETER	RANKING BY SOURCE: BRAND REX UNAGED	BRAND REX AGED	CHAMPLAIN AGED	FILOTEX	MCAIR UNAGED	MCAIR AGED	TENSOLITE AGED	THERMATICS AGED
Room Temp.	201	201	201		101	101	201	201
	256	241	256		106	156	206	256
	246	256	241		156	106	256	241
	(206	246	206		146	141	241	206
	(236	206	246		136	146	246	246
	241	236	236		141	136	236	236
70°C	201	201	201	NO TEST DATA	101	101	201	201
	246	241	246		106	156	246	246
	256	256	256		146	146	256	256
	241	246	241		156	141	241	236
	236	236	236		141	106	236	206
	206	206	206		136	136	206	241ND
150°C	201	201	201		101	101	201	201
	246	(241	246		156	156	246	246
	256	(246	256		146	141	241	256
	241	256	241		141	146	256	241
	236	236	236		136	136	236	236
	206	206	206		106	106	206	206
200°C	201	201	201		101	101	201	246
	246	241	246		146	146	246	241
	256	246	256		156	141	241	256
	241	(236	241		141	156	256	236
	236	(256	236		136	136	236	206
	206	206	206		106	106	206	201ND

(These constructions had identical numerical values. The lowest construction number is listed first.)
ND No Data

TABLE RR-14

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: DYNAMIC CUT THRU AFTER 1000 HRS @ 200°C
TEST SPECIMEN: 22TN

TEST PARAMETER	BRAND REX UNAGED	BRAND REX AGED	CHAMPLAIN AGED	FILOTEX	MCAIR UNAGED	MCAIR AGED	TENSOLITE AGED	THERMATICS AGED
Room Temp.	202	202	202		102	102	202	202
	(242	242	242		157	157	242	242
	257	257	257		137	142	257	257
	237	237	207		147	147	207	207
	247	207	237		107	137	237	237
	207	247	247		142	107	247	247
70°C	202	202	202	NO TEST DATA	102	102	202	202
	257	257	257		142	157	257	257
	242	242	247		137	142	242	242
	247	247	242		157	147	247	237
	237	237	237		147	137	237	247
	207	207	207		107	107	207	207
150°C	202	202	202		102	102	202	202
	257	247	257		157	157	247	247
	242	(242	247		147	142	(237	257
	247	257	242		142	147	242	242
	237	237	237		137	137	257	237
	207	207	207		107	107	207	207
200°C	202	(247	202		102	102	242	202
	(242	257	257		157	142	202	247
	257	202	247		147	157	247	257
	247	242	242		142	147	257	237
	237	237	237		137	137	237	207ND
	207	207	207		107	107	207	242ND

(These constructions had identical numerical values. The lowest construction number is listed first.)
ND No Data

TABLE RR-15

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: DYNAMIC CUT THRU AFTER 1000 HRS @ 200°C
TEST SPECIMEN: 26TN

TEST PARAMETER	BRAND REX UNAGED	BRAND REX AGED	CHAMPLAIN AGED	FILOTEX	MCAIR UNAGED	MCAIR AGED	TENSOLITE AGED	THERMATICS AGED
Room Temp.	203	203	203		103	103	203	203
	248	248	208		108	158	208	208
	258	(243	258		138	108	258	248
	(238	258	248		148	148	243	258
	243	208	243		158	143	248	243
	208	238	238		143	138	238	238
70°C	203	203	203	NO TEST DATA	103	103	203	203
	238	248	248		143	148	248	243
	258	243	258		138	143	243	248
	243	(208	243		108	158	238	258
	248	258	208		148	138	258	238
	208	238	238		158	108	208	208
150°C	203	243	203		103	103	203	203
	(238	248	243		148	143	248	248
	243	203	248		(138	138	243	243
	(248	238	238		143	148	238	238
	258	258	258		158	158	258	258
	208	208	208		108	108	208	208
200°C	203	243	203		103	103	203	203
	248	203	248		138	143	248	248
	243	248	243		148	138	243	243
	238	238	238		143	148	238	238
	258	258	258		158	158	258	258
	208	208	208		108	108	208	208

(These constructions had identical numerical values. The lowest construction number is listed first.)

TABLE RR-16

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: FLEX LIFE AFTER 1000 HOURS @ 200°C
TEST SPECIMEN: 22TK/22TN/26TN/22SJ/26ASJ

TEST SPECIMEN	RANKING BY SOURCE							
	BRAND REX		CHAMPLAIN	FILOTEX	MCAIR		TENSOLITE	THERMATICS
	UNAGED	AGED	AGED	AGED	UNAGED	AGED	AGED	AGED
22TK	201	201	246	201	101	101	201	201
	246	246	201	236	156	146	246	246
	256	241	241	246	141	156	236	256
	206	256	236	256	106	141	25C	241
	236	236	256	241	136	136	241	206
	241	206	206	206	146	106	206	236
22TN	257	202	202	202	102	102	202	202
	202	257	237	237	157	157	237	257
	237	242	257	257	142	147	257	237
	247	237	242	247	137	137	242	242
	242	247	247	242	107	142	247	247
	207	207	207	207	147	107	207	207
26TN	203	258	258	203	103	158	258	258
	258	203	203	258	158	103	203	203
	238	238	248	238	148	148	238	248
	248	243	238	248	108	143	248	238
	243	248	243	243	143	108	243	243
	208	208	208	208	138	138	208	208
22-2SJ	244	239	244		144			249
	249	259	249		239			244
	259	209	239		159			209
	239	249	259		109			239
	209	244	209		149			204
	204	204	204		104			259
26A-2SJ	245	240	245		145			
	205	245	240		160			
	260	250	210		150			
	210	210	250		240			
	240	260	205		110			
	250	205	260		105			

TABLE RR-17

ROUND ROBIN TEST RESULT COMPARISON (BY RANKING)

NAME OF TEST: NOTCH PROPAGATION AFTER 1000 HOURS @ 200°C
TEST SPECIMEN: 22TK/22TN/26TN - 67% NOTCH DEPTH

TEST SPECIMEN	BRAND REX UNAGED	BRAND REX AGED	CHAMPLAIN AGED	FILOTEX AGED	MCAIR UNAGED	MCAIR AGED	TENSOLITE AGED	THERMATICS AGED
22TK	(206	(241	(236	236	(101	(101	241	(236
	(236	256	(241	256	(106	(136	201	(241
	(241	236	256	241	(136	(141	246	256
	256	246	246	246	(141	(146	(206	201
	246	201	201	201	(146	156	256	246
	201	206	206	206	156	106	236	206
22TN	(242	(242	(237	257	(102	(102	242	(242
	257	257	(242	237	(107	(137	247	257
	247	237	257	242	(137	(142	237	237
	237	247	247	202	(142	(147	207	247
	202	202	202	207	(147	157	(202	207
	207	207	207	247	157	107	257	202
26TN	(238	(243	(203	238	(103	(103	(238	(203
	(243	248	238	243	(108	(138	(243	(238
	(248	258	248	248	(138	(143	258	(243
	258	203	243	203	(143	(148	248	258
	203	238	258	258	(148	158	203	248
	208	208	208	208	158	108	208	208

(These constructions had identical numerical values. The lowest construction number is listed first.)

TABLE RR-18

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: NOTCH PROPAGATION AFTER 1000 HOURS @ 200°C
TEST SPECIMEN: 22TK/22TN/26TN - 50% NOTCH DEPTH

TEST SPECIMEN	BRAND REX UNAGED	BRAND REX AGED	CHAMPLAIN AGED	FILOTEX AGED	MCAIR AGED	TENSOLITE AGED	THERMATICS AGED
	RANKING BY SOURCE						
22TK	(201	(201	236**	256	101**	(241	(236
	(206	(236	241**	236	136**	256	(241
	(236	(241	256**	241	141**	236	256
	(241	256	(201	201	146**	246	201
	(246	246	246	206	156**	201	246
	256	206	206	246	106	206	206
22TN	(202	(242	237**	242	102**	242	(237
	(207	(247	242**	257	137**	237	(242
	(237	257	257**	237	142**	247	257
	(242	237	(202	202	147**	257	247
	(247	202	247	247	157**	202	202
	257	207	207	207	107	207	207
26TN	(203	(238	203**	(203	103**	(203	(203
	(208	(243	238**	(238	138**	(238	(238
	(238	(248	(243	243	143**	(243	(243
	(243	258	(248	248	148**	(248	258
	(248	203	258	258	158**	258	248
	258	208	208	208	103	208	208

(These constructions had identical numerical values. The lowest construction number is listed first.)
**100% pass on 67% notch and not retested on 50% notch depth.

TABLE RR-19

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: TIME CURRENT TO SMOKE
TEST SPECIMEN: 22TK/22TN/26TN/22SJ/26ASJ

TEST SPECIMEN	RANKING BY SOURCE: BRAND REX	CHAMPLAIN	FILOTEX	DAC	TENSOLITE	THERMATICS
22TK	201	241		101		241
	241	201		141		201
	246	246		146		246
	206	206		136		256
	(236	256		156		236
	256	236		106		206
22TN	202	202	NO TEST DATA	(102	NO TEST DATA	247
	247	242		147		242
	242	237		(137		202
	237	257		142		257
	207	207		157		237
	257	247		107		207
26TN	203	203		(103		243
	243	243		(138		203
	248	248		148		238
	238	238		143		248
	208	208		158		258
	258	258		108		208
22-2SJ	244	244		149		244
	249	239		159		209
	239	249		139		259
	259	259		104		204
	209	209		144		239
	204	204		109		249
26A-2SJ	210	245		140		240
	245	240		150		210
	(205	250		145		245
	250	210		105		250
	240	260		110		205
	260	205		160		260

(These constructions had identical numerical values. The lowest construction number is listed first.)

TABLE RR-20

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: FLAMMABILITY
TEST SPECIMEN: 22TK/22TN/22SJ

TEST SPECIMEN	RANKING BY SOURCE						
	BRAND REX	CHAMPLAIN	FAA	FILOTEX	MCAIR	TENSOLITE	THERMATICS
22TK	201	246	246	201	101	241	246
	(241	201	241	241	(141	246	241
	246	241	201	236	146	201	201
	(206	256	236	246	136	236	236
	(236	236	256	206	156	206	256
	256	206	206	256	106	256	206
22TN	247	202	242	242	(142	247	202
	(237	242	247	247	102	242	242
	242	247	202	202	137	202	237
	(202	237	237	237	147	237	247
	(207	207	207	257	157	207	257
	257	257	257	207	107	257	207
22-2SJ	(204	249	204	249	144	209	249
	(249	239	259	204	149	249	259
	259	204	249	239	104	239	204
	(209	209	239	244	109	204	239
	244	259	209	209	159	244	209
	239	244	244	259	139ND	259	244

(These constructions had identical numerical values. The lowest construction number is listed first.)
ND - No Data

TABLE RR-21

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: WIRE FUSING TIME
TEST SPECIMEN: 22TK/22TN/26TN

TEST SPECIMEN	RANKING BY SOURCE					
	BRAND REX	CHAMPLAIN	FILOTEX	MCAIR	TENSOLITE	THERMATICS
22TK	201	241	NO TEST DATA	141	NO TEST DATA	236
	241	201		101		241
	236	246		146		201
	246	206		156		246
	(206	236		106		206
	256	256		136		256
22TN	242	242		142		(207
	(202	202		102		237
	237	247		147		242
	247	257		157		247
	(207	237		107		(202
	257	207		137		257
26TN	243	243		103		203
	(203	203		143		243
	(208	248		138		238
	238	208		148		(248
	248	238		108		258
	258	258		158		208

(These constructions had identical numerical values. The lowest construction number is listed first.)

TABLE RR-22

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: INSULATION TENSILE STRENGTH
TEST SPECIMEN: 22TK/22TN/26TN/22SJ/26SJ

TEST SPECIMEN	RANKING BY SOURCE: BRAND REX	CHAMPLAIN	FILOTEX	MCAIR	TENSOLITE	THERMATICS
22TK	201	201	201	101	201	201
	246	246	246	146	246	246
	256	236	236	156	256	236
	236	256	256	236	236	256
	206	241	241	141	241	241
	241	206	206	106	206	206
22TN	202	202	202	102	202	202
	257	237	237	147	237	237
	237	257	247	237	242	242
	242	242	257	142	257	257
	207	247	242	157	247	247
	247	207	207	107	207	207
26TN	203	203	203	N	203	203
	238	238	238	O	243	243
	258	243	258		238	238
	243	248	248	T	258	258
	208	258	243	E	248	208
	248ND	208	208	S	208	248ND
				T		
22-2SJ						239
						204
						249
						259
						209
						244
26A2SJ						205
						240
						250
						260
						210
						245

(These constructions had identical numerical values. The lowest construction number is listed first.)
ND - No Data

TABLE RR-23

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: INSULATION ELONGATION
TEST SPECIMEN: 22TK/22TN/26TN

TEST SPECIMEN	RANKING BY SOURCE					
	BRAND REX	CHAMPLAIN	FILOTEX	MCAIR	TENSOLITE	THERMATICS
22TK	241	241	241	141	241	241
	206	206	206	106	206	236
	256	236	236	146	201	206
	246	201	246	156	246	246
	236	256	256	236	236	256
	201	246	201	101	256	201
22TN	242	242	207	142	242	207
	207	207	242	107	207	242
	247	237	237	147	237	237
	237	202	202	237	247	202
	202	257	247	102	202	247
	257	247	257	157	257ND	257
26TN	208	243	208	NO TEST	243	243
	243	248	238		248	208
	238	208	243		208	238
	(203	238	203		238	258
	258	203	258		203	203
	248ND	258	248		258	248ND

(These constructions had identical numerical values. The lowest construction number is listed first.)
ND - No Data

TABLE RR-24

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: FINISHED DIAMETER
TEST SPECIMEN: 22TK/22TN/26TN/22SJ/26ASJ

TEST SPECIMEN	RANKING BY SOURCE: BRAND REX	CHAMPLAIN	FAA	FILOTEX	MCAIR	TENSOLITE	THERMATICS
22TK	236	236	236	201	136	236	201
	201	201	201	236	146	201	246
	256	246	246	246	156	246	236
	246	256	256	256	101	256	256
	206	206	206	206	141	206	206
	241	241	241	241	106	241	241
22TN	202	202	202	202	137	207	242
	207	247	207	(207	107	247	202
	237	207	237	247	147	202	247
	247	237	247	237	102	237	237
	257	257	257	257	157	257	207
	242	242	242	242	142	242	257
26TN	208	208	208	208	138	208	208
	203	203	203	203	(103	203	(203
	248	238	248	248	148	238	248
	238	248	238	238	108	248	238
	258	258	258	258	158	258	258
	243	243	243	243	143	243	243
22-2SJ	204	204	204	204	109	204	204
	259	259	209	209	104	209	249
	(209	209	249	249	159	249	259
	249	239	259	(239	239	259	209
	239	249	239	259	149	239	239
	244	244	244	244	144	244	244
26A2SJ	250	210	250	210	110	250	240
	(210	240	240	250	150	240	210
	240	250	205	240	105	210	(205
	205	205	210	205	240	205	250
	245	260	245	260	145	245	245
	260	245	260	245	160	260	260

(These constructions had identical numerical values. The lowest construction number is listed first.)

TABLE RR-25

ROUND ROBIN TEST RESULT COMPARISON
(BY RANKING)

NAME OF TEST: FINISHED WEIGHT
TEST SPECIMEN: 22TK/22TN/26TN/22SJ/26ASJ

TEST SPECIMEN	RANKING BY SOURCE: BRAND REX	CHAMPLAIN	FAA	FILOTEX	MCAIR	TENSOLITE	THERMATICS
22TK	201	201	201	206	101	201	201
	256	256	256	201	136	256	256
	246	(236	246	256	156	246	246
	236	246	236	246	146	236	236
	206	206	206	236	106	206	206
	241	241	241	241	141	241	241
22TN	202	202	202	202	137	202	202
	207	207	207	207	157	207	207
	237	257	237	257	102	257	257
	257	237	257	247	107	(237	(237
	247	247	247	237	147	247	247
	242	242	242	242	142	242	242
26TN	203	203	203	203	103	203	203
	208	208	208	208	108	208	208
	248	248	248	248	138	248	248
	258	258	258	238	158	258	258
	238	238	238	258	148	238	238
	243	243	243	243	143	243	243
22-2SJ	204	204	204	204	104	204	204
	239	259	259	239	159	239	239
	259	239	239	259	109	259	259
	209	209	209	209	239	209	209
	249	249	249	249	149	249	249
	244	244	244	244	144ND	244	244
26A-2SJ	205	205	205	205	105	205	205
	240	240	240	240	240	240	240
	210	210	210	210	150	210	210
	260	260	260	260	110	260	260
	250	250	250	250	160	250	250
	245	245	245	245	145ND	245	245

(These constructions had identical numerical values. The lowest construction number is listed first.)

TABLE [illegible]-26

ABRASION

COMPARATIVE STANDINGS

CONSTR 22IK	BR REX			CHAMPL			FILOTEX			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT
201	1	2	2	3	2	2	1	4	2	4	3	3	2	3	3	3	2	2	2.0	2.6	2.2
206	6	4	3	6	3	3	6	6	3	3	4	4	5	2	1	5	3	3	5.6	3.6	2.6
236	1	3	4	2	5	5	3	2	4	1	1	1	3	6	4	4	5	4	2.6	4.2	4.2
241	1	6	5	4	6	6	4	5	5	5	6	6	4	5	5	2	4	5	3.0	5.2	5.2
246	1	1	1	1	1	1	1	1	1	2	2	2	1	1	2	1	1	1	1.0	1.0	1.2
256	1	5	6	5	4	4	5	3	6	6	5	5	6	4	6	6	6	6	4.6	4.4	5.6
	1Ø 150	2Ø 150	3Ø 150	1Ø 150	2Ø 150	3Ø 150	1Ø 150	2Ø 150	3Ø 150	1Ø 150	2Ø 150	3Ø 150				1Ø 150	2Ø 150	3Ø 150	1Ø 150	2Ø 150	3Ø 150
201	1	2	2	1	2	1	1	2	2	2	3	2				2	2	2	1.3	2.0	1.8
206	6	6	6	6	6	6	6	5	5	6	6	6				6	6	6	6.0	5.8	5.8
236	1	3	4	1	3	4	3	3	4	4	2	3				3	3	4	2.0	3.0	4.0
241	4	4	3	4	4	3	4	4	3	3	4	4				4	4	3	4.0	4.0	3.0
246	1	1	1	1	1	2	1	1	1	1	1	1				1	1	1	1.0	1.0	1.3
256	5	5	6	5	5	5	5	6	5	5	5	5				5	5	5	5.0	5.3	5.3

CONSTR 22IN	BR REX			CHAMPL			FILOTEX			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT	1ØRT	2ØRT	3ØRT
202	4	3	1	3	5	1	6	4	1	4	2	3	4	5	1	4	4	1	4.2	4.2	1.0
207	5	4	2	5	2	4	4	3	4	3	4	4	5	3	4	3	2	4	4.4	2.8	3.6
237	1	4	3	2	3	3	2	2	2	1	1	1	2	2	2	2	3	3	1.8	2.8	2.6
242	6	6	6	6	6	6	3	6	5	5	6	6	3	6	6	6	6	5	4.8	6.0	5.6
247	1	1	3	1	1	2	1	1	3	2	1	2	1	1	3	1	1	1	1.0	1.0	2.4
257	3	2	5	4	4	5	5	5	6	6	5	5	6	4	5	5	5	6	4.6	4.0	5.4
	1Ø 150	2Ø 150	3Ø 150	1Ø 150	2Ø 150	3Ø 150	1Ø 150	2Ø 150	3Ø 150	1Ø 150	2Ø 150	3Ø 150				1Ø 150	2Ø 150	3Ø 150	1Ø 150	2Ø 150	3Ø 150
202	3	3	3	3	3	4	4	4	4	4	4	3				4	4	4	3.5	3.5	3.8
207	6	6	3	6	6	6	6	6	6	6	6	6				6	6	6	6.0	6.0	5.3
237	2	2	1	1	2	2	2	2	3	2	2	3				2	2	3	1.8	2.0	2.3
242	4	4	3	4	4	3	3	3	2	3	3	2				3	3	2	3.5	3.5	2.8
247	1	1	1	2	1	1	1	1	1	1	1	1				1	1	1	1.3	1.0	1.0
257	5	5	3	5	5	5	5	5	5	6	5	5				5	5	5	5.0	5.3	4.5

TABLE RR-27

DYNAMIC CUT THRU

COMPARATIVE STANDINGS

CONSTR 22TK	BR REF RT	BR REF 70°C	BR REF 150°C	BR REF 200°C	CHAMPL RT	CHAMPL 70°C	CHAMPL 150°C	CHAMPL 200°C	MCAIR RT	MCAIR 70°C	MCAIR 150°C	MCAIR 200°C	TENSOL RT	TENSOL 70°	TENSOL 150°C	TENSOL 200°C	THERM RT	THERM 70°C	THERM 150°C	THERM 200°C	AVG W/O MCAIR RT	AVG W/O MCAIR 70°C	AVG W/O MCAIR 150°C	AVG W/O MCAIR 200°C
201	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	ND	1.0	1.0	1.0	1.0
206	5	6	6	6	4	6	6	6	3	5	6	6	2	6	6	6	4	5	6	5	3.8	5.8	6.0	5.8
236	6	5	5	4	6	5	5	5	6	6	5	5	6	5	5	5	6	4	5	4	6.0	4.8	5.0	4.5
241	2	2	2	2	3	4	4	4	4	4	3	3	4	4	3	3	3	ND	4	2	3.0	3.3	3.3	2.8
246	4	4	2	3	5	2	2	2	5	3	4	2	5	2	2	2	5	2	2	1	4.8	2.5	2.0	2.0
256	3	3	4	4	2	3	3	3	2	2	2	4	3	3	4	4	2	3	3	3	2.5	3.0	3.5	3.5

CONSTR 22TN	BR REF RT	BR REF 70°C	BR REF 150°C	BR REF 200°C	CHAMPL RT	CHAMPL 70°C	CHAMPL 150°C	CHAMPL 200°C	MCAIR RT	MCAIR 70°C	MCAIR 150°C	MCAIR 200°C	TENSOL RT	TENSOL 70°	TENSOL 150°C	TENSOL 200°C	THERM RT	THERM 70°C	THERM 150°C	THERM 200°C	AVG W/O MCAIR RT	AVG W/O MCAIR 70°C	AVG W/O MCAIR 150°C	AVG W/O MCAIR 200°C
202	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1.0	1.0	1.0	1.8
207	5	6	6	6	4	6	6	6	6	6	6	6	4	6	6	6	4	6	6	ND	4.3	6.0	6.0	6.0
237	4	5	5	5	5	5	5	5	5	5	5	4	5	5	3	5	5	4	5	4	4.8	4.8	4.5	4.8
242	2	3	3	4	2	4	4	4	3	3	3	2	2	3	3	1	2	3	3	ND	2.0	3.3	3.3	3.0
247	6	4	2	1	6	3	3	3	4	4	4	4	6	4	2	3	6	5	2	2	6.0	4.0	2.3	2.3
257	3	2	3	1	3	2	2	2	2	2	2	3	3	2	5	4	3	2	3	3	3.0	2.0	3.3	2.5

CONSTR 26TN	BR REF RT	BR REF 70°C	BR REF 150°C	BR REF 200°C	CHAMPL RT	CHAMPL 70°C	CHAMPL 150°C	CHAMPL 200°C	MCAIR RT	MCAIR 70°C	MCAIR 150°C	MCAIR 200°C	TENSOL RT	TENSOL 70°	TENSOL 150°C	TENSOL 200°C	THERM RT	THERM 70°C	THERM 150°C	THERM 200°C	AVG W/O MCAIR RT	AVG W/O MCAIR 70°C	AVG W/O MCAIR 150°C	AVG W/O MCAIR 200°C
203	1	1	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1.0	1.0	1.5	1.3
208	5	4	6	6	2	5	6	6	3	6	6	6	2	6	6	6	2	6	6	6	2.8	5.3	6.0	6.0
238	6	6	4	4	6	6	4	4	6	5	3	3	6	4	4	4	6	5	4	4	6.0	5.3	4.0	3.8
243	3	3	1	1	5	4	2	3	4	3	2	2	5	3	3	3	3	2	3	3	4.0	3.0	2.3	2.5
248	2	2	2	3	4	2	3	2	4	2	4	4	5	2	2	2	3	3	2	2	3.5	2.3	2.3	2.3
258	3	4	5	5	3	3	5	5	2	4	5	5	3	5	5	5	4	4	5	5	3.3	4.0	5.0	5.0

ND - No Data

TABLE RR-28

FLEX LIFE

COMPARATIVE STANDINGS

CONSTR	BR PEX			CHAMPL			FILOTEX			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN
201	1			2			1			1			1			1			1.2		
206	6			6			6			6			6			5			5.8		
236	5			4			2			5			3			6			4.0		
241	3			3			5			4			5			4			4.0		
246	2			1			3			2			2			2			2.0		
256	4			5			4			3			4			3			4.0		
202		1			1			1			1			1			1			1.0	
207		6			6			6			6			6			6			6.0	
237		4			2			2			4			2			3			2.6	
242		3			4			5			5			4			4			4.0	
247		5			5			4			3			5			5			4.8	
257		2			3			3			2			3			2			2.6	
203			2			2			1			2			2			2			1.8
208			6			6			6			5			6			6			6.0
238			3			4			3			6			3			4			3.4
243			4			5			5			4			5			5			4.8
248			5			3			4			3			4			3			3.8
258			1			1			2			1			1			1			1.2

TABLE RR-29A

NOTCH PROPAGATION - 67%

COMPARATIVE STANDINGS

CONSTR	BR REX			CHAMPL			FILOTEX			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N
201	5			5			5			1			2			4			4.2		
206	6			6			6			6			4			6			5.6		
236	3			1			1			1			6			1			2.4		
241	1			1			3			1			1			1			1.4		
246	4			4			4			1			3			5			4.0		
256	1			3			2			5			4			1			2.2		
202		5			5			4			1			5			6			5.0	
207		6			6			5			6			4			5			5.2	
237		3			1			2			1			3			3			2.4	
242		1			1			3			1			1			1			1.4	
247		4			4			6			1			2			4			4.0	
257		1			3			1			1			5			1			2.2	
203			4			1			4			1			5			1			3.0
208			6			6			6			6			6			6			6.0
238			5			1			1			1			1			1			1.8
243			1			4			2			1			1			1			1.8
248			1			3			3			1			4			5			3.2
258			3			5			5			5			1			1			3.0

TABLE RR-298

NOTCH PROPAGATION - 50%

COMPARATIVE STANDINGS

CONSTR	RE REX			CHAMPL			FILOTEX			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N
201	1			4			4			1			5			4			3.6		
206	6			6			5			6			6			6			5.8		
236	1			1			2			1			3			1			1.6		
241	1			1			3			1			1			1			1.4		
246	5			4			6			1			4			5			4.8		
256	1			1			1			1			1			1			1.0		
202		5			4			4			1			5			5			4.6	
207		6			6			6			6			6			6			6.0	
237		4			1			3			1			2			1			2.2	
242		1			1			1			1			1			1			1.0	
247		1			4			5			1			3			4			3.4	
257		1			1			2			1			4			1			1.8	
203			5			1			1			1			1			1			1.8
208			6			6			6			6			6			6			6.0
238			1			1			1			1			1			1			1.0
243			1			3			1			1			1			1			1.4
248			1			3			4			1			1			5			2.8
258			1			3			5			1			1			1			2.2

TABLE RR-30

TIME - CURRENT TO SMOKE

COMPARATIVE STANDINGS

ONSTR	BR REX			CHAMFL			DAC			TENSOL			THERM			AVG W/O DAC		
	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	2FTN
201	1			2			1						2			1.7		
206	4			4			6						6			4.7		
236	5			6			4						5			5.3		
241	2			1			2						1			1.3		
246	3			3			3						3			3.0		
256	5			5			5						4			4.7		
202		1			1			1						3			1.7	
207		5			5			6						6			5.3	
237		4			3			3						5			4.0	
242		3			2			3						2			2.3	
247		2			6			1						1			3.0	
257		6			4			5						4			4.7	
203			1			1			1						2			1.3
208			5			5			6						6			5.3
238			4			4			1						3			3.7
243			2			2			4						1			1.7
248			3			3			1						4			3.3
258			6			6			5						5			5.7

TABLE RR-31
FLAMMABILITY
COMPARATIVE STANDINGS

CONSTR	BR REX		CHAMPL		FAA		FILOTEX		MCAIR		TENSOL		THERM		AVG W/O MCAIR	
	22TK	22TN	22TK	22TN	22TK	22TN	22TK	22TN	22TK	22TN	22TK	22TN	22TK	22TN	22TK	22TN
201	1		2		3		1		1		3		3		2.2	
206	4		6		6		5		6		5		6		5.3	
236	4		5		4		3		4		4		4		4.0	
241	2		3		2		2		2		1		2		2.0	
246	2		1		1		4		2		2		1		1.8	
256	4		4		5		6		5		6		5		5.0	
202		4		1		3		3		1		3		1		2.5
207		4		5		5		6		6		5		6		5.2
237		2		4		4		4		3		4		3		3.5
242		2		2		1		1		1		2		2		1.7
247		1		3		2		2		4		1		4		2.2
257		4		6		6		5		5		6		5		5.3

TABLE RR-32
WIRE FUSING TIME
COMPARATIVE STANDINGS

CONSTR	BR REX			CHAMPL			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN
201	1			2			2						3			2.0		
206	5			4			5						5			4.7		
236	3			5			6						1			3.0		
241	2			1			1						2			1.7		
246	4			3			3						4			3.7		
256	5			6			4						6			5.7		
202		2			2			2						5			3.0	
207		5			6			5						1			4.0	
237		2			5			6						1			2.7	
242		1			1			1						3			1.7	
247		4			3			3						4			3.7	
257		5			4			4						5			4.7	
203			2			2			1						1			1.7
208			2			4			5						6			4.0
238			2			5			3						3			3.3
243			1			1			2						2			1.3
248			5			3			4						4			4.0
259			5			6			6						4			5.3

TABLE RR-33

INSULATION TENSILE STRENGTH

COMPARATIVE STANDINGS

CONSTR	BR REX			CHAMPL			FILOTEX			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN
201	1			1			1			1			1			1			1.0		
206	5			6			6			6			6			6			5.8		
236	4			3			3			4			4			3			3.4		
241	6			5			5			5			5			5			5.2		
246	2			2			2			2			2			2			2.0		
256	3			4			4			3			3			4			3.6		
202		1			1			1			1			1			1			1.0	
207		5			6			6			6			6			6			5.8	
237		3			2			2			3			2			2			2.2	
242		4			4			5			4			3			3			4.0	
247		6			5			3			2			5			5			4.8	
257		2			3			4			5			4			4			3.4	
203			1			1			1						1			1			1.0
208			5			6			6						6			5			5.6
238			2			2			2						3			3			2.4
243			4			3			5						2			2			3.2
248			ND			4			4						5			ND			4.3
258			3			5			3						4			4			3.8

ND - No Data

TABLE RH-34

INSULATION ELONGATION

COMPARATIVE STANDINGS

CONSTR	BR REX			CHAMPL			FILOTEX			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TH	22TK	22TN	26TN	22TK	22TN	26TN
201	6			4			6			6			3			6			5.0		
206	2			2			2			2			2			3			2.2		
236	5			3			3			5			5			2			3.6		
241	1			1			1			1			1			1			1.0		
246	4			6			4			3			4			4			4.4		
256	3			5			5			4			6			5			4.8		
202		5			4			4			5			5			4			4.4	
207		2			2			1			2			2			1			1.6	
237		4			3			3			4			3			3			3.2	
242		1			1			2			1			1			2			1.4	
247		3			6			5			3			4			5			4.6	
257		6			5			6			6			6			6			5.8	
203			4			5			4						5			5			4.6
208			1			3			1						3			2			2.0
238			3			4			2						4			3			3.2
243			2			1			3						1			1			1.6
248			ND			2			6						2			ND			3.3
258			4			6			5						6			4			5.0

ND - No Data

TABLE RA-35

FINISHED DIAMETER

COMPARATIVE STANDINGS

CONSTR	BR REX			CHAMPI			FAA			FILOTEX			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N	221K	221N	261N
201	2			2			2			1			4			2			1			1.7		
206	5			5			5			5			6			5			5			5.0		
236	1			1			1			2			1			1			3			1.3		
241	6			6			6			6			5			6			6			6.0		
246	4			3			3			3			2			3			2			3.0		
256	3			4			4			4			3			4			4			3.8		
202		1			1			1			1			4			3			2			1.5	
207		2			3			2			2			2			1			5			2.5	
237		3			4			3			4			1			4			4			3.7	
242		6			6			6			6			6			6			1			5.2	
247		4			2			4			2			3			2			3			2.8	
257		5			5			5			5			5			5			6			5.2	
203			2			2			2			2			2			2			2			2.0
208			1			1			1			1			4			1			1			1.0
238			4			3			4			4			1			3			4			3.7
243			6			6			6			6			6			6			6			6.0
248			3			4			3			3			2			4			2			3.2
258			5			5			5			5			5			5			5			5.0

F-33615-89-C-5605

TABLE RR-36

FINISHED WEIGHT

COMPARATIVE STANDINGS

CONSTR	BR REX			CHAMPL			FAA			FILOTEX			MCAIR			TENSOL			THERM			AVG W/O MCAIR		
	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN	22TK	22TN	26TN
201	1			1			1			2			1			1			1			1.2		
206	5			5			5			1			5			5			5			4.3		
236	4			3			4			5			2			4			4			4.0		
241	6			6			6			6			6			6			6			6.0		
246	3			3			3			4			4			3			3			3.2		
256	2			2			2			3			3			2			2			2.2		
202		1			1			1			1			3			1			1			1.0	
207		2			2			2			2			4			2			2			2.0	
237		3			4			3			5			1			4			4			3.8	
242		6			6			6			6			6			6			6			6.0	
247		5			5			5			4			5			4			4			4.5	
257		4			3			4			3			2			3			3			3.3	
203			1			1			1						1			1			1			1.0
208			2			2			2						2			2			2			2.0
238			5			5			5						5			3			5			4.6
243			6			6			6						6			6			6			6.0
248			3			3			3						3			5			3			3.4
258			4			4			4						4			4			4			4.0

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TABLE RR-37A

CONSTRUCTIONS

(AVERAGE OF ALL STANDINGS COMPARED TO MCAIR STANDING)

TEST PARAMETER		201	206	236	241	246	256	202	207	237	242	247	257	203	208	238	243	248	258
ABRASION (RR-26)																			
10-RT	AVG	2.0	5.6	2.6	3.0	1.0	4.6	4.2	4.4	1.8	4.8	1.0	4.6						
	MCAIR	4	3	1	5	2	6	4	3	1	5	2	6						
20-RT	AVG	2.6	3.6	4.2	5.2	1.0	4.4	4.2	2.8	2.8	6.0	1.0	4.0						
	MCAIR	3	4	1	6	2	5	2	4	1	6	1	5						
30-RT	AVG	2.2	2.6	4.2	5.2	1.2	5.6	1.0	3.6	2.6	5.6	2.4	5.4						
	MCAIR	3	4	1	6	2	5	3	4	1	6	2	5						
10-150°C	AVG	1.3	6.0	2.0	4.0	1.0	5.0	3.5	6.0	1.8	3.5	1.3	5.0						
	MCAIR	2	6	4	3	1	5	4	6	2	3	1	5						
20-150°C	AVG	2.0	5.8	3.0	4.0	1.0	5.3	3.5	6.0	2.0	3.5	1.0	5.3						
	MCAIR	3	6	2	4	1	5	4	6	2	3	1	5						
30-150°C	AVG	1.8	5.8	4.0	3.0	1.3	5.3	3.8	5.3	2.3	2.8	1.0	4.5						
	MCAIR	2	6	3	4	1	5	3	6	3	2	1	5						
DYNAMIC CUT-THRU (RR-27)																			
RT	AVG	1.0	3.8	6.0	3.0	4.8	2.5	1.0	4.3	4.8	2.0	6.0	3.0	1.0	2.8	6.0	4.0	3.5	3.3
	MCAIR	1	3	6	4	5	2	1	[illegible]	5	3	4	2	1	3	6	4	4	2
70°C	AVG	1.0	5.8	4.8	3.3	2.5	3.0	1.0	6.0	4.8	3.3	4.0	2.0	1.0	5.3	5.3	3.0	2.3	4.0
	MCAIR	1	5	6	4	3	2	1	6	5	3	4	2	1	6	5	3	2	4
150°C	AVG	1.0	6.0	5.0	3.3	2.0	3.5	1.0	6.0	4.5	3.3	2.3	3.3	1.5	6.0	4.0	2.3	2.3	5.0
	MCAIR	1	6	5	3	4	2	1	6	5	3	4	2	1	6	3	2	4	5
200°C	AVG	1.0	5.8	4.5	2.8	2.0	3.5	1.8	6.0	4.8	3.0	2.3	2.5	1.3	6.0	3.8	2.5	2.3	5.0
	MCAIR	1	6	5	3	2	4	1	6	5	2	4	3	1	6	3	2	4	5
FLEX LIFE (RR-28)																			
	AVG	1.2	5.8	4.0	4.0	2.0	4.0	1.0	6.0	2.6	4.0	4.8	2.6	1.8	6.0	3.4	4.8	3.8	1.2
	MCAIR	1	6	5	4	2	3	1	6	4	4	3	2	2	5	6	4	3	1
NOTCH PROPAGATION(RR-29A)																			
67%	AVG	4.2	5.6	2.4	1.4	4.0	2.2	5.0	5.2	2.4	1.4	4.0	2.2	3.0	6.0	1.8	1.8	3.2	3.0
	MCAIR	1	6	1	1	1	5	1	6	1	1	1	1	1	1	1	1	1	1
50%	AVG (RR-29B)	3.6	5.8	1.6	1.4	4.8	1.0	4.6	6.0	2.2	1.0	3.4	1.8	1.8	6.0	1.0	1.4	2.8	2.2
	MCAIR	1	6	1	1	1	1	1	6	1	1	1	1	1	6	1	1	1	1
TIME-CURRENT TO SMOKE(RR-30)																			
	AVG	1.7	4.7	5.3	1.3	3.0	4.7	1.7	5.3	4.0	2.3	3.0	4.7	1.3	5.3	3.7	1.7	3.3	5.7
	DAC	1	6	4	2	3	5	1	6	3	3	1	5	1	6	1	4	1	5
FLAMMABILITY(RR-31)																			
	AVG	2.2	5.3	4.0	2.0	1.8	5.0	2.5	5.2	3.5	1.7	2.2	5.3						
	MCAIR	1	6	4	2	2	5	1	6	3	1	4	5						
WIRE FUSING TIME(RR-32)																			
	AVG	2.0	4.7	3.0	1.7	3.7	5.7	3.0	4.0	2.7	1.7	3.7	4.7	1.7	4.0	3.3	1.3	4.0	5.3
	MCAIR	2	5	6	1	3	4	2	5	6	1	3	4	1	5	3	2	4	6

TABLE RR-37B

CONSTRUCTIONS

(AVERAGE OF ALL STANDINGS COMPARED TO MCAIR STANDING)

TEST PARAMETER	201	206	236	241	246	256	202	207	237	242	247	257	203	208	238	243	248	258
INSUL TENSILE STRGTH(RR-33)																		
AVG	1.0	5.8	3.4	5.2	2.0	3.6	1.0	5.8	2.2	4.0	4.8	3.4	1.0	5.6	2.4	3.2	4.3	3.8
MCAIR	1	6	4	5	2	3	1	6	3	4	2	5	ND	ND	ND	ND	ND	ND
INSUL ELONGATION(RR-34)																		
AVG	5.0	2.2	3.6	1.0	4.4	4.8	4.4	1.6	3.2	1.4	4.5	5.8	4.6	2.0	3.2	1.6	3.3	5.0
MCAIR	6	2	5	1	3	4	5	2	4	1	3	6	ND	ND	ND	ND	ND	ND
FINISHED DIAMETER(RR-35)																		
AVG	1.7	5.0	1.3	6.0	3.0	3.8	1.5	2.5	3.7	5.2	2.8	5.2	2.0	1.0	3.7	6.0	3.2	5.0
MCAIR	4	6	1	5	2	3	4	2	1	6	3	5	2	4	1	6	2	5
FINISHED WEIGHT(RR-36)																		
AVG	1.2	4.3	4.0	6.0	3.2	2.2	1.0	2.0	3.8	6.0	4.5	3.3	1.0	2.0	4.6	6.0	3.4	4.0
MCAIR	1	5	2	6	4	3	3	4	1	6	5	2	1	2	3	6	5	4

ND - No Data

11.0 OVERALL SUMMARY

All four main program objectives have been successfully completed. First, performance requirements for aircraft wire insulation were identified. Second, tests addressing the performance requirements were selected, and a weight factor was determined for each test to provide a ranking of performance requirements. Third, ten new wire insulation constructions (provided by: Barcel, Brand Rex, Champlain, DuPont, Filotex, Gore, NEMA, Tensolite, and Thermatics) were selected for the test program. Two baselines, M81381 and M22759, were also tested as benchmarks. Fourth, preliminary specifications were prepared for the four top candidates.

Testing was split into two sections, Screening and Full Performance. The Screening tests were performed first on the ten candidates to screen out performance inadequacies. A statistical analysis of all Screening Tests allowed the candidate field to be narrowed down to four candidates (Filotex, NEMA, Tensolite, and Thermatics). Additional consideration ensured that a single source candidate was not chosen for the final four and that all four candidates were varied in construction.

The Full Performance Tests were performed on the four selected candidates. Following completion of the tests, an overall statistical analysis was performed, encompassing all Screening and Full Performance test results on the four selected candidates. Final weighted statistical analysis of the candidates and baselines follows:

1.	Filotex	8.22
2.	Tensolite	8.23
3.	M81381	9.21
4.	Thermatics	9.39
5.	NEMA #3	10.48
6.	M22759	11.38

Screening and Full Performance Tests were grouped in performance categories and a statistical analysis was performed for each individual test group category.

Filotex, the first place candidate, scored high (one of the top two constructions) in the General, Electrical, Thermal, and Weight and Dimensional Test categories. It performed in the middle (either third or fourth place) in the Combat Damage, Environmental, Mechanical, and Marking Test categories. It did not perform at the bottom (fifth or sixth) in any test categories.

Tensolite, the second place candidate, scored high in the Combat Damage, Electrical, Environmental, and Mechanical Test categories. It performed in the middle of the General, Marking, and Thermal Test categories. It performed last in the Weight and Dimensional Test category.

M81381, the third place candidate, scored high in the Mechanical and Weight and Dimensional Test categories. It scored in the middle in the Electrical category, and scored at the bottom of the General, Combat Damage, Environmental, Marking, and Thermal Test categories.

Thermatics, the fourth place candidate, scored high in the General and Thermal Test categories. It scored in the middle in the Combat Damage, Electrical, and Mechanical Test categories, and scored at the bottom of the Environmental, Marking, and Dimensional and Weight categories.

NEMA #3, the fifth place candidate, scored high in the Marking Test category. It scored in the middle of the Environmental, Dimensional and Weight, and Thermal Test categories, and at the bottom in the General, Combat Damage, Electrical, and Mechanical Test categories.

M22759, the sixth place candidate, scored high in the Combat Damage, Environmental, and Marking Test categories. It scored in the middle in the General and Dimensional and Weight categories, and at the bottom of Electrical, Mechanical, and Thermal Test categories.

Cable test results were not included in any of the overall weighted statistical analyses. However, a separate statistical analysis was performed to rank performance of cable candidates. Final statistical analysis of the cable samples follows in two columns. The first column is an overall number including Screening and Full Performance test results. Filotex is not included in this ranking because they did not provide cable early enough to participate in the Screening Tests. The second column shows the statistical analysis based on Full Performance tests only.

SCREENING & FULL PERFORMANCE			FULL PERFORMANCE		
1.	TENSOLITE	7.15	1.	TENSOLITE	3.84
2.	M81381	8.65	2.	FILOTEX	6.97
3.	M22759	8.81	3.	THERMATICS	9.13
4.	THERMATICS	8.86	4.	M22759	9.19
5.	NEMA #3	9.93	5.	NEMA #3	10.09
			6.	M81381	13.58

Tensolite's extruded PFA jacket performed the best when considering Full Performance only or both Full Performance and Screening Test results.

Filotex and Tensolite, the two top performers from the overall weighted statistical analysis, were subjected to two additional tests: Assembly, Handling, Installation, Removal, and Repair Evaluation; and Chemical and Thermal Analysis. Both Filotex and Tensolite performed as well as or better than the comparison baseline, M22759, in the Assembly, Handling, Installation, Removal, and Repair Evaluation.

Both M81381 and M22759 were tested as baselines in the Chemical and Thermal Analysis test. Results showed that little of the base resins used in any of the four constructions is degraded during aging. However, high temperature aging causes: (1) loss or destruction of the adhesive used to seal tapes, (2) loss of certain volatile species such as anti-oxidants, (3) embrittlement (cross-linking) of extruded ETFE resins, and (4) in some instances, copper may diffuse through silver (or nickel)

plating on the conductor.

In addition to the developed test program summarized above, Dry Arc Propagation Tests incorporating a 270 Vdc power system were conducted. Results showed that no tested insulations are able to inhibit 270 Vdc arc propagation in a circuit with no additional protection added. However, there are circuit protection devices available which can sufficiently inhibit propagation to maintain interconnect system integrity.

Three arc propagation tests were evaluated in this program. A goal of the program was to identify wire constructions which minimize arc propagation yet retain the thermal and mechanical properties of MIL-W-81381. The top three constructions (Filotex, Tensolite, and Thermatics) appear to meet the above goal.

A Round Robin Test program was completed to address repeatability/variability of test results. Data comparisons were made for all testers for all constructions tested. There was a variation in actual data; however, the ranking showed correlation trends. Candidates one and two as a group tended to be uniform in ranking and the sixth place candidate tended to be uniform across the range of testers. The variation in actual data suggests that further refinement of SAE test procedures/descriptions may be required.

12.0 OBSERVATIONS

Throughout the test program, observations have been made regarding the performance of individual candidates and baseline constructions. Some of the observations have noted difficulties with constructions. A noted difficulty with the Filotex construction includes the submission of two different constructions. In order to fulfill a last minute request for candidate submission, Filotex provided a production version of the proposed candidate. This first submission was a nickel plated conductor with PTFE dispersion. Nickel plating was used due to processing adversities with silver plated conductor and PTFE dispersion. Conductor strand blocking occurred during the PTFE dispersion curing process. The second submission, provided between Screening and Full Performance Test programs, was changed per MCAIR's request, to meet the original proposed construction of a silver plated conductor. However, due to processing difficulties, a PTFE dispersion could not be provided on a silver plated conductor. An FEP dispersion, which requires lower curing temperatures, was substituted for the PTFE dispersion. This second submission is not manufacturable on an industrial scale. It was processed in laboratory conditions, and Filotex does not have plans to develop it into a production construction. The two separate construction submissions makes it difficult to correlate data between Screening and Full Performance Test sections.

Concerns were noted with the Tensolite candidate. Tensolite submitted a candidate that was marginally at or beyond the size and weight limits of the specified military parameters. The extra material may have been partially responsible for its good results in Environmental and Mechanical Tests and outstanding performance in Combat Damage and Electrical Tests. The Tensolite draft specification sheets originally prepared by the insulator reflect diameters and weights beyond those established in M81381. A subsequent revision of the draft specification sheets resulted in a reduction of weights and diameters that would make this construction an acceptable choice.

A tape sealing problem was observed on the Thermatics candidate in the AC Corona Test and consistent marginal performance was noted among tests incorporating a wet dielectric test. The candidate exhibited an unexpectedly high leakage current. Teledyne has identified this as a processing problem due to a learning curve of processing the combination of PTFE and polyimide. Different processing conditions than have traditionally been used for FEP/polyimide constructions are required. Teledyne does not anticipate this as being an insurmountable problem. A problem of insulation adherence to the conductor was also noted in the Hudson International Round Robin test report. This problem may be a product of improper sintering of the tapes.

A noted difficulty with NEMA #3 was its poor performance in the BSI Dry Arc Propagation Test. Two factors which may

have contributed to the NEMA #3's poor performance include the initial aging before the test, which may have thermally degraded the extruded XL ETFE, and the inner layer of a fluoropolymer/polyimide tape next to the conductor with only a 0.0001" of fluorocarbon adjacent to the conductor.

Performance observations include a noted significant degradation of M81381 during the Verification of Retained Properties Test. M81381 showed the most degradation of the final six constructions tested. This was an unexpected result due to its outstanding performance in the Mechanical Test category, from which the Verification of Retained Properties Tests were taken.

Another observation was that the mechanical performance of M22759 appears to increase during some Verification of Retained Properties Tests following the aging process. A significant increased performance is shown on the 22 gauge specimens in the Abrasion Test and a small increase is shown on the 22 gauge, 5.8 mil, thin wall specimens in the Dynamic Cut Through Test. No increased performance was noted for the M22759/33-26 gauge specimens in any of the four tests. An explanation for what appears to be a high percentage of improvement in the Abrasion Test is that the cycles to failure in the unaged specimens were so low that a only a few additional cycles to failure achieved for the aged specimens resulted in a large percentage improvement. For example, the unaged 22 gauge, 5.8 mil, thin wall specimen ran for 4 cycles at 21°C with a three pound weight. The aged specimen ran for

5.5 cycles under the same conditions. This resulted in a 38% increase in performance. The only substantial increase in performance occurred in the Abrasion Test on the 22 gauge specimens run at 21°C with a one pound weight. The unaged 22 gauge, 5.8 mil, thin wall specimen ran for 45 cycles to failure, and the aged specimen ran for 138 cycles to failure (for a recorded 207% increase in performance). The unaged 22 gauge, 8.6 mil, thick wall specimen ran for 180 cycles to failure, and the aged specimen ran for 323 cycles to failure (for a recorded 80% increase in performance). This correlates with Chemical and Thermal Analysis findings that short term aging of XL ETFE seems to enhance some mechanical properties.

A further observation noted on the M22759 construction was that the 26 gauge specimens were PD-135 rather than CS95. This was also true for the first submission of Filotex's candidate. It is expected that the CS 95 would provide longer flex life than would PD-135 conductor. Other performance values could be affected.

An additional observation made during the statistical analysis of the test program was that weighting factors could have been more widely spread to provide a greater variance in test importance. A wider spread may have resulted in less unanimity between weighted and unweighted statistical scores and a wider spread in final rankings.

An analysis of the thermal index data suggests the top three candidate constructions (Filotex, Tensolite, and Thermatics) could be rated at temperatures significantly

higher than 200°C (all Thermal Index Tests were conducted using silver plated conductor). The primary limitation is the inability to use silver plated conductors at temperatures higher than 200°C. Nickel plated conductor can be used in applications as high as 260°C and would extend the operating temperature capability of the new candidate constructions. A nickel plated conductor would also allow higher wire processing temperatures by the insulators. This would reduce difficulties in manufacturing the proposed new wire constructions. Higher processing temperatures would also provide better sealing of the fluoropolymer layers and possibly improve mechanical and electrical properties.

Observations on availability of insulation materials, cost, manufacturing concerns, and environmental impact of processing were solicited from and provided by manufacturers of the four final candidates. Those responses are provided below:

Filotex:

Availability of Materials - All materials are available from a minimum of two different suppliers.

Cost - No cost estimates were provided by Filotex for the silver plated candidate.

Manufacturability - Strand blocking of silver plated conductor is caused by sintering processes of PTFE, polyimide 616 insulation curing, and FEP topcoat curing. Filotex is not able to manufacture the

candidate on an industrial scale with a silver plated conductor. They are able manufacture the candidate with a nickel plated conductor. However, American processors are presently uncomfortable in manufacturing the candidate due to the extrusion of a thin layer (approximately 0.002" wall) of PTFE as the first layer of the construction for smaller gauge sizes.

Environmental Impact - All the materials used in the construction have been in volume production for many years, and production of this candidate would have no adverse environmental consequences.

NEMA #3:

Availability - Materials used are the same as those used in M81831 and M22759.

Cost - The cost will be greater than M22759 XL ETFE, but should be comparable with M81381.

Manufacturability - Initial problems of some blistering of the extrusion were encountered, causing problems with producing long lengths of the construction. This has been reduced considerably with experience and process development. The construction should be readily producible by multiple sources on a large scale.

Environmental Impact - All the materials used in the construction have been in volume production for many

years, and production of this candidate would have no adverse environmental consequences.

Tensolite:

Availability - All materials are available from a minimum of two different suppliers.

Cost - Candidate cost would be increased between 11% and 16% for 22 gauge conductor and 25% for 26 gauge conductor over the M81381 cost. The 26 gauge candidate cost would increase only 20% if PD-135 alloy were specified instead of CS95.

Manufacturability - No manufacturing problems were encountered. Adjustments can be made for outer diameter and weight by controlling the thickness of the PTFE on the first tape. These adjustments were not made for test samples due to time constraints.

Environmental Impact - All the materials used in the construction have been in volume production for many years, and production of this candidate would have no adverse environmental consequences.

Thermatics:

Availability - The films used for the construction were provided by DuPont on a developmental basis and are not yet standard products. DuPont has indicated their intention to establish these films as standard products if the aerospace wire and cable industry has

a need for them. One problem was identified with the roll put-ups available. For best performance in the taping operation, the tapes need to be provided in rolls that are a long length and do not have an tendency for the tapes to slip off the edge of the roll.

Cost - An increase of less than 10% is expected to be incurred over baseline constructions.

Manufacturability - Two manufacturing problems were encountered. The first was that the outer tape edge rolled over when short tape lengths from the small pad rolls were being spliced together. This resulted in visual defects. The second problem involved determining optimum processing conditions for the PTFE based sealant layer. Teledyne anticipates that both problems are correctable. This construction should be readily producible by multiple sources.

Environmental Impact - No negative environmental impacts are known or anticipated from production of this construction.

13.0 CONCLUSIONS AND RECOMMENDATIONS

This comprehensive test program demonstrated that alternative wire constructions are available that perform better than M22759 and M81381 if a balance of properties is measured. An analysis of the top three constructions (Filotex, Tensolite, and Thermatics) shows that each contains approximately 65% and 35% fluoropolymer and polyimide, respectively. By contrast, thin wall MIL-W-81381 contains 15% and 85% of fluoropolymer and polyimide, respectively. The increased amount of fluoropolymer effectively reduces arc propagation and increases environmental resistance and flexibility. The presence of a polyimide layer greatly enhances the mechanical properties of the insulation construction. These constructions address arc propagation susceptibility, thermal stability concerns, and chaffing resistance, which are three of the major concerns of the aerospace wiring industry.

This program demonstrated that a wire performance test document can be effectively used to identify the best wire insulation for a given application. The comparison approach can provide designers with the optimal wire construction for the selected environment.

The Filotex candidate was the first place construction in the overall, weighted statistical analysis of all of the Screening and Full Performance Tests combined. This construction cannot presently be recommended for use in U.S. military aircraft for two reasons. The first reason is that

there is limited availability of manufacturers who can extrude PTFE as thinly as specified for the Filotex construction. The second reason involves the plating of the conductor. Numerous aerospace companies use silver plated conductor. The Filotex candidate cannot be produced on an industrial scale with a silver plated conductor. The nickel plated construction, however, performed very well in the Screening Tests and would be an excellent candidate for use in applications where nickel plating is acceptable. The thin layer of extruded PTFE may be replaced by a tape wrapped PTFE so that U.S. manufacturers are able to produce the construction. Results of the inner tape wrapped PTFE may not correlate with results of the inner extruded PTFE, and additional tests would need to be performed before this construction could be recommended.

The Tensolite candidate came in second place in the overall, weighted statistical analysis. This construction cannot be recommended for use in U.S. military aircraft at this time due to the size discrepancies between current baseline constructions and the Tensolite construction. In a retrofit situation, the Tensolite construction, if built to the draft specification sheets, could be sufficiently larger and heavier, and the additional weight and volume could be a problem in many military aircraft. The larger volume of material may have been a factor in some of the performance values. If and when this construction can be manufactured to M81381 weights and diameters, it would be a good alternative choice for direct replacement of M22759 or M81381. A proposed

mil spec slant sheet has been prepared using M81381 diameter and weights as a minimum requirement. If the smaller volume material can qualify to the performance requirements, it should be a very acceptable construction. See exhibit A of this report.

The Thermatics candidate came in third place in the overall, weighted statistical analysis. This is the construction recommended for incorporation into U.S. military aircraft. The sealing difficulties and insulation to conductor adherence noted in section 12.0 are expected to be resolved through improved processing experience. This candidate is manufacturable by a number of sources and remains within the specified size constraints. This construction has balanced properties when compared to MIL-W-81381 and MIL-W-22759 wiring evaluated in this program. The Thermatics construction has improved handling characteristics and significant arc propagation resistance when compared to MIL-W-81381. The construction has superior mechanical properties at high temperatures (above 70°C) when compared to the evaluated MIL-W-22759 wiring. Recommendations are to: Use this construction as a direct replacement for M81381 on existing aircraft for further evaluation; Consider this construction during evaluation of new aerospace systems; Use the material for retrofit of M22759 or M81381 wire. The materials used in the Thermatics construction are well known and rapid qualification of the wiring is expected. Improved versions of the Thermatics construction are expected to

perform at a higher level than the wiring evaluated in this program. A proposed mil spec slant sheet has been prepared for this construction and is found in Exhibit A of this report.

Both the Filotex and Tensolite candidates were excellent performers and have shown considerable potential. However, additional work is required with both constructions before meeting the program wiring application guidelines. The Thermatics candidate is the only construction which meets all guidelines at this time, and is recommended for a flight test program. The use of nickel plated conductor with this construction would allow the wiring to be rated at a higher temperature and enhance the performance of the insulation by permitting higher manufacturing process temperatures. The primary concern will be producing good crimped and soldered connections.

14.0 BAR GRAPH PERFORMANCE SUMMARY

Enclosed in this section of the report is a copy of all the comparison plots generated.

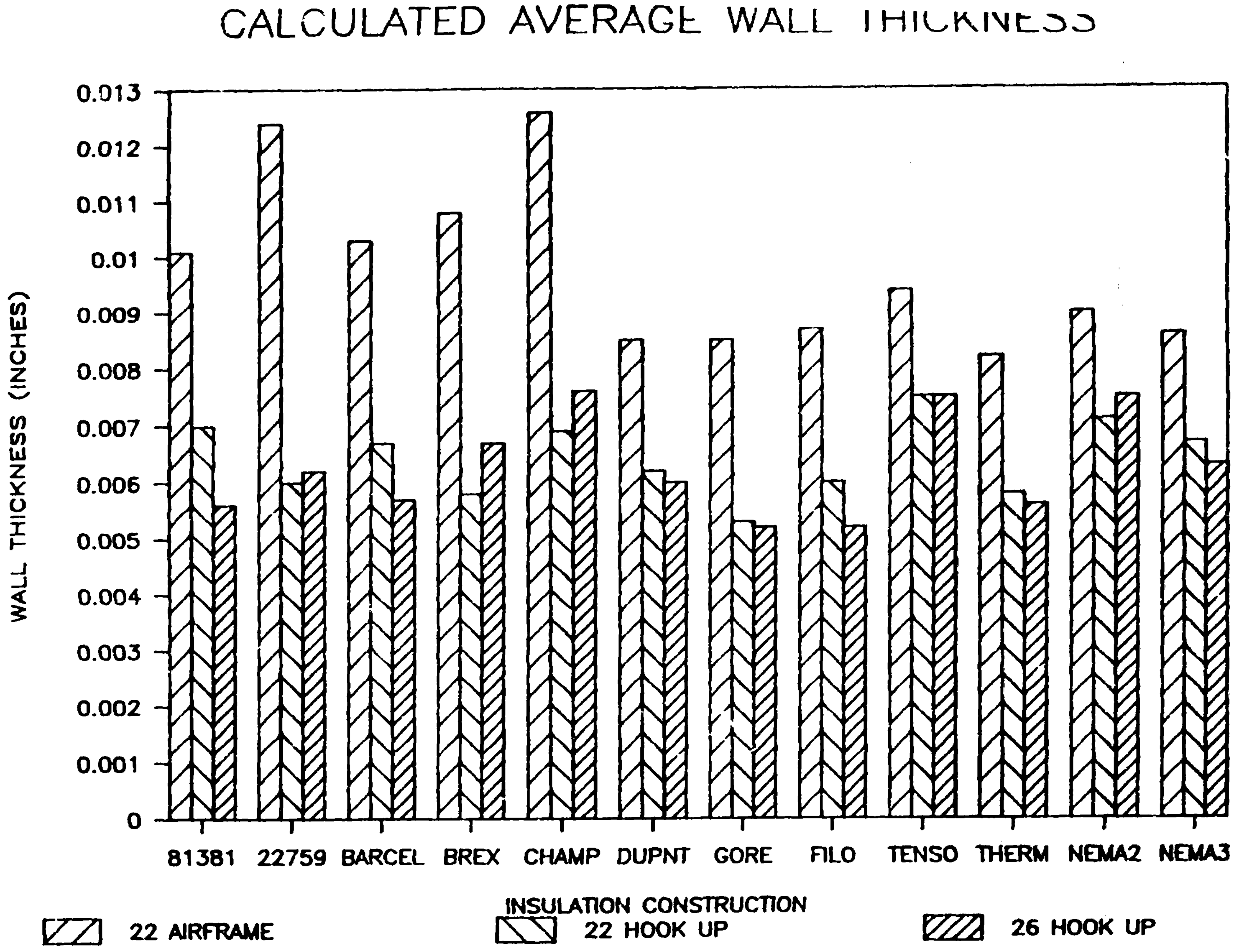


FIGURE 3.1 - CALCULATED AVERAGE WALL THICKNESS

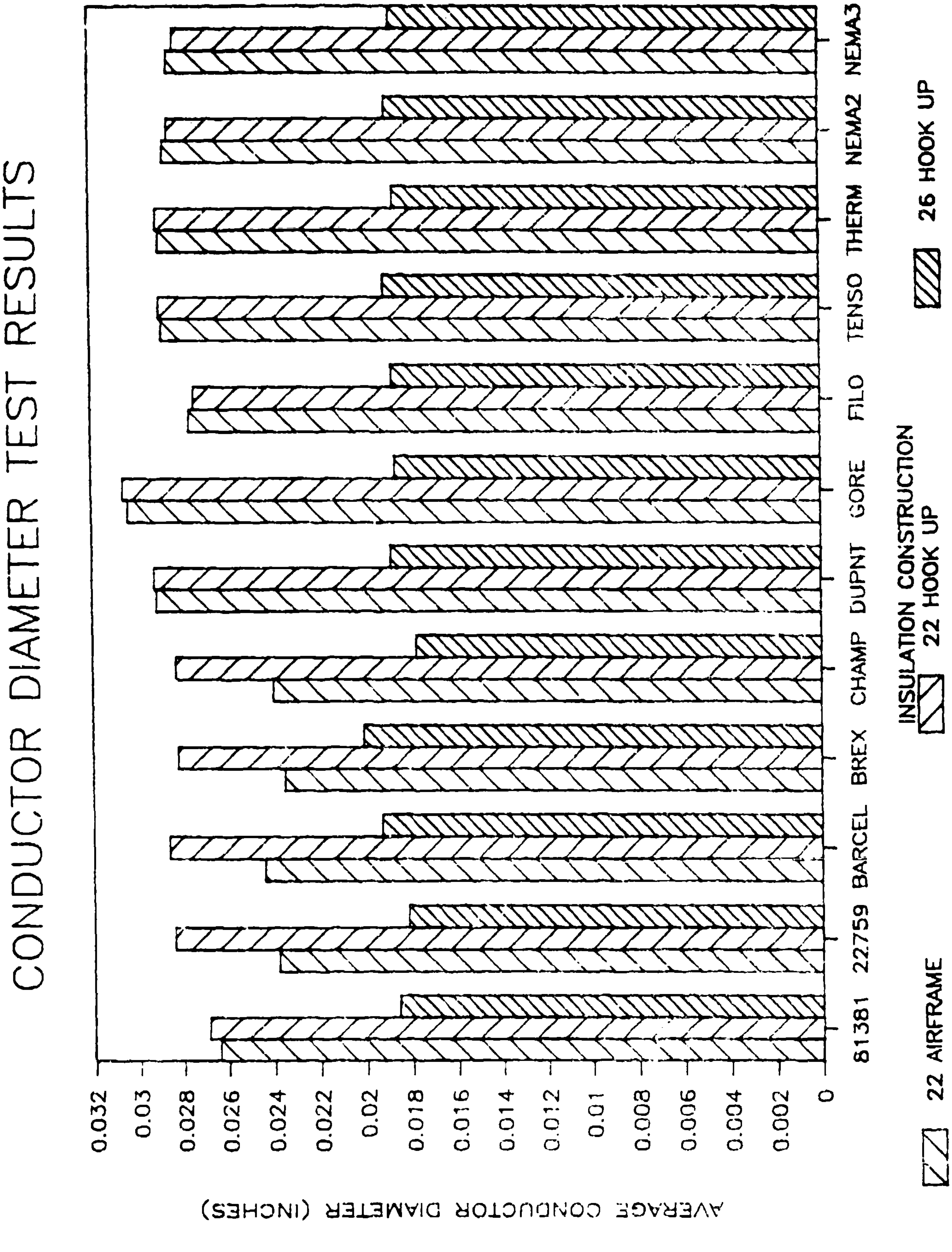


FIGURE 3.7 - CONDUCTOR DIAMETER TEST RESULTS

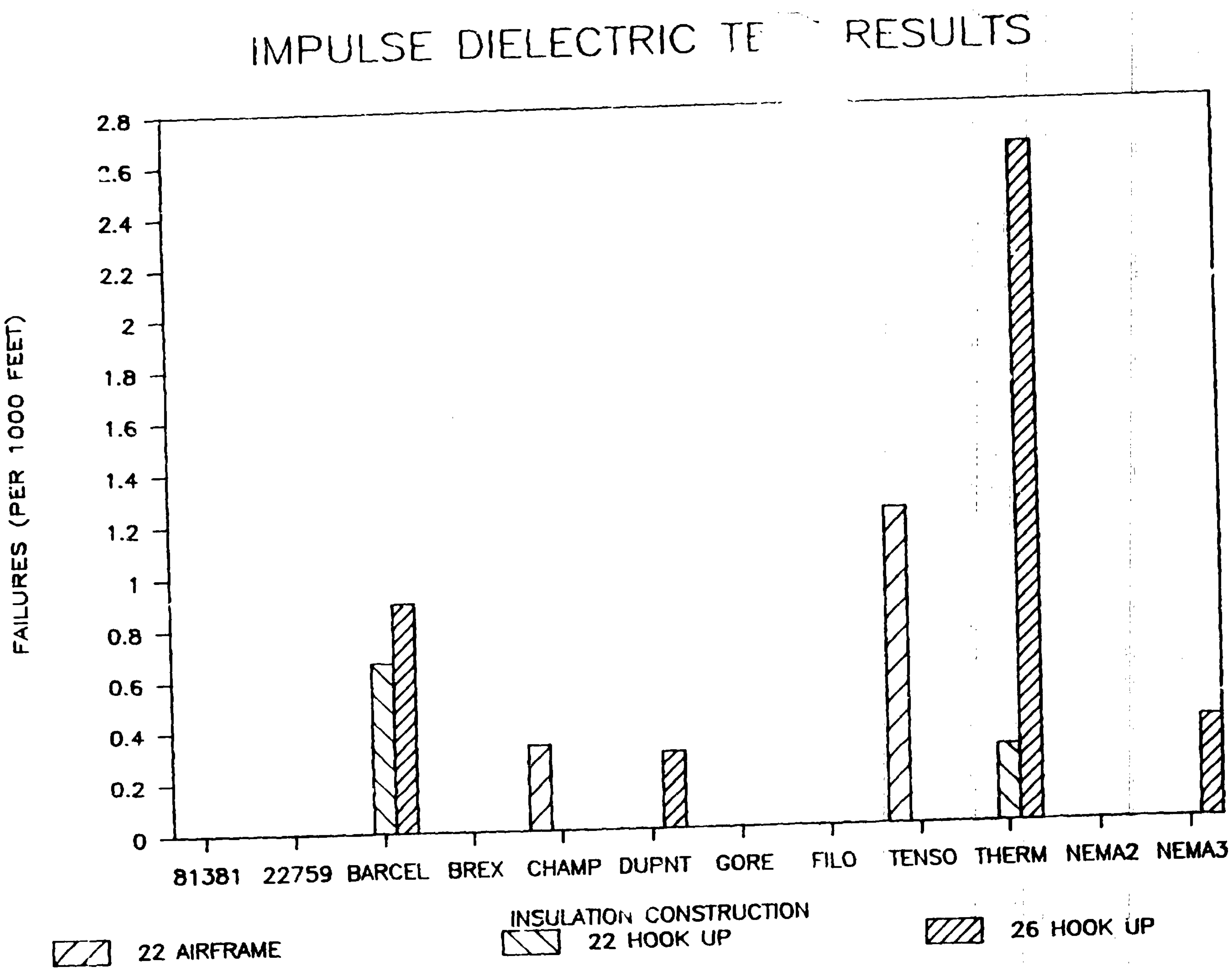


FIGURE 3.8 - IMPULSE DIELECTRIC TEST RESULTS

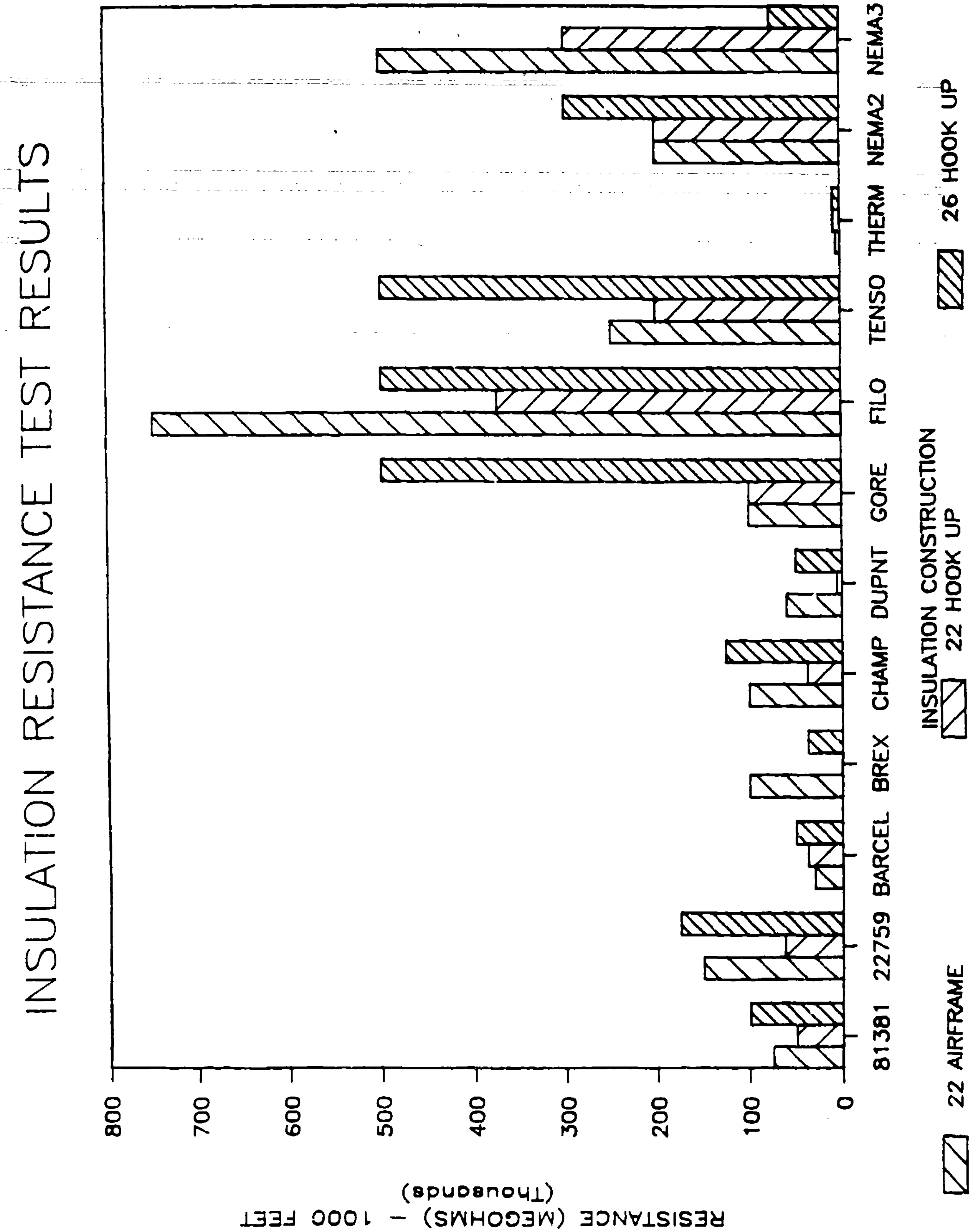


FIGURE 3.9 - INSULATION RESISTANCE TEST RESULTS

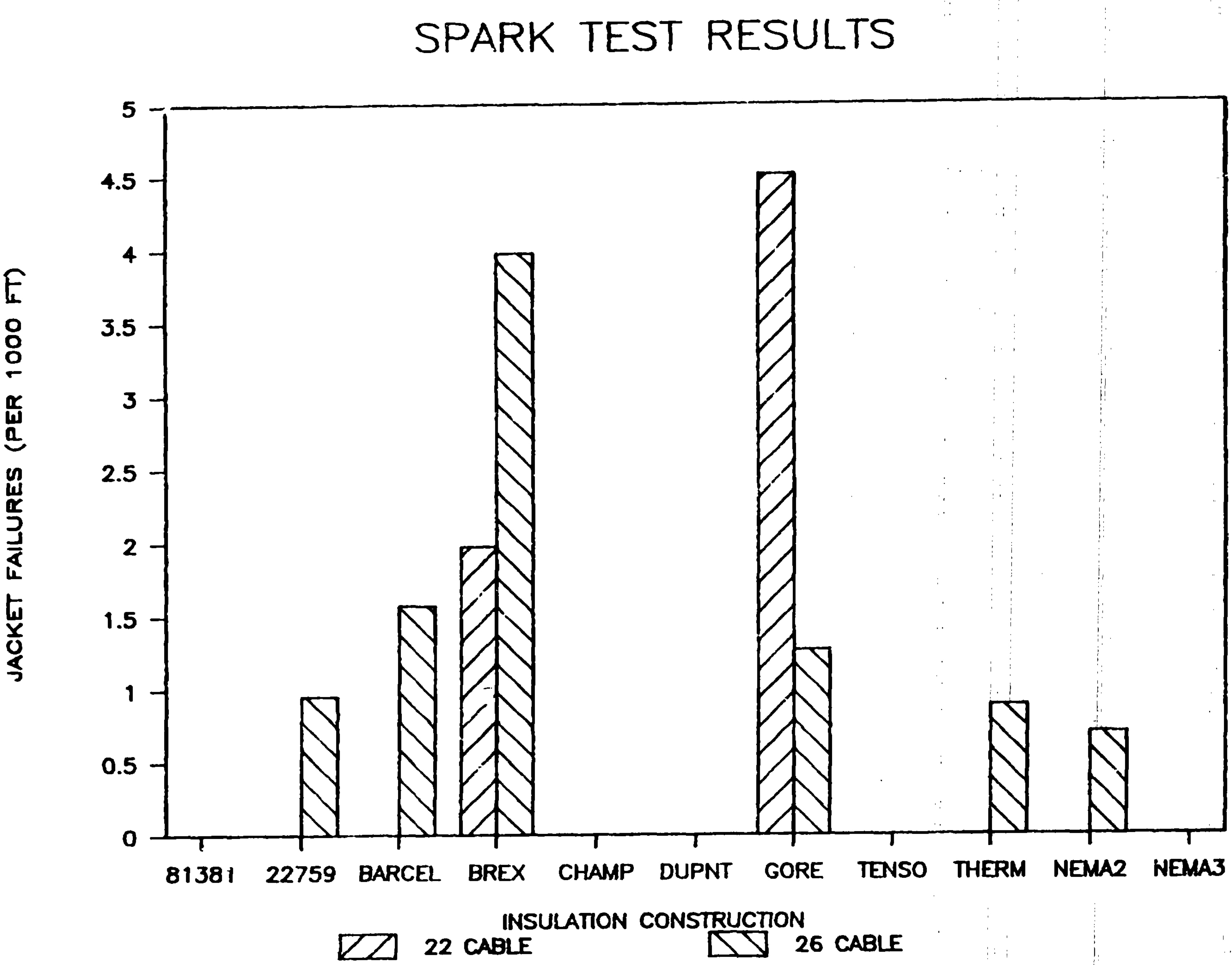


FIGURE 3.11 - SPARK TEST RESULTS

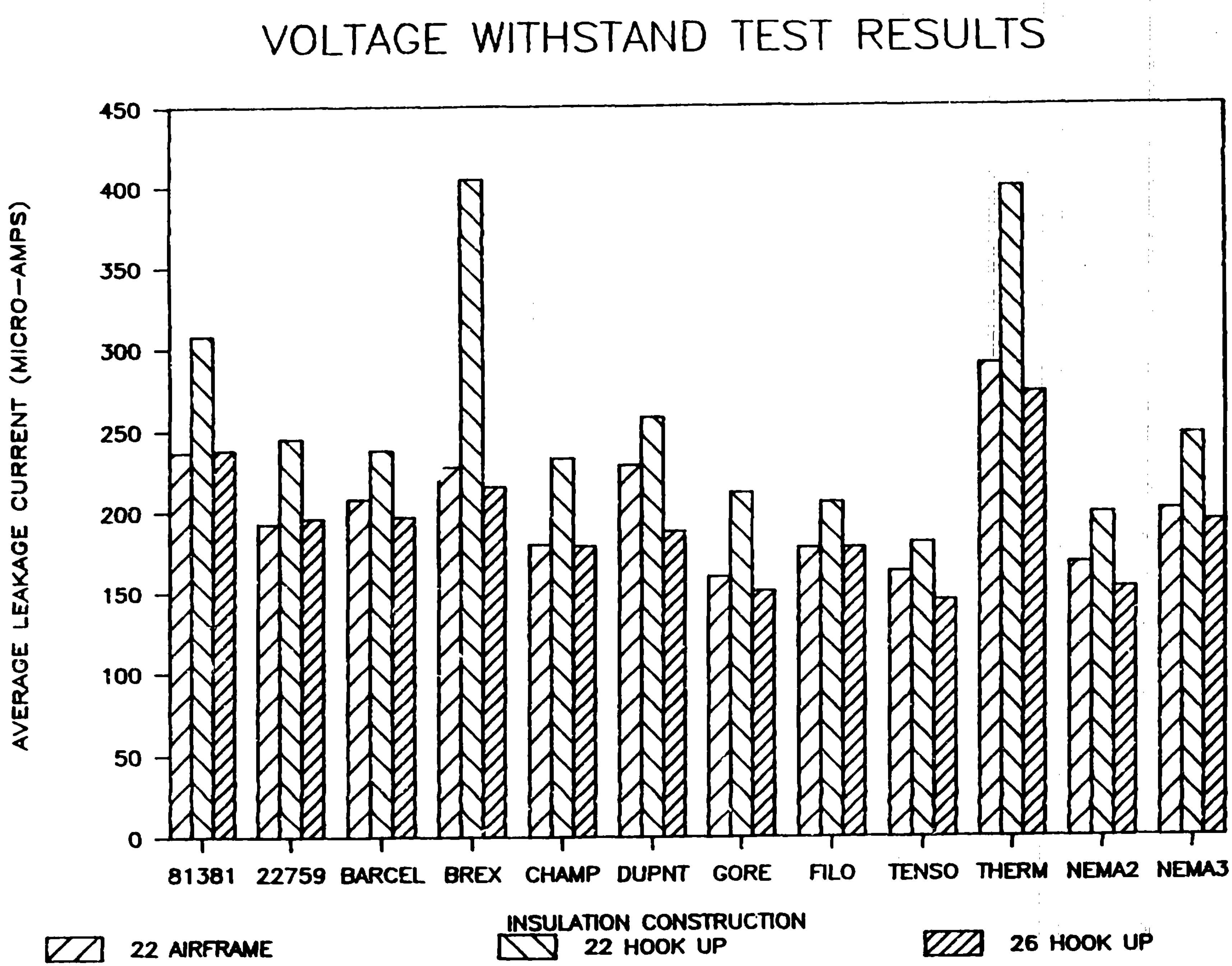


FIGURE 3.12 - VOLTAGE WITHSTAND TEST RESULTS

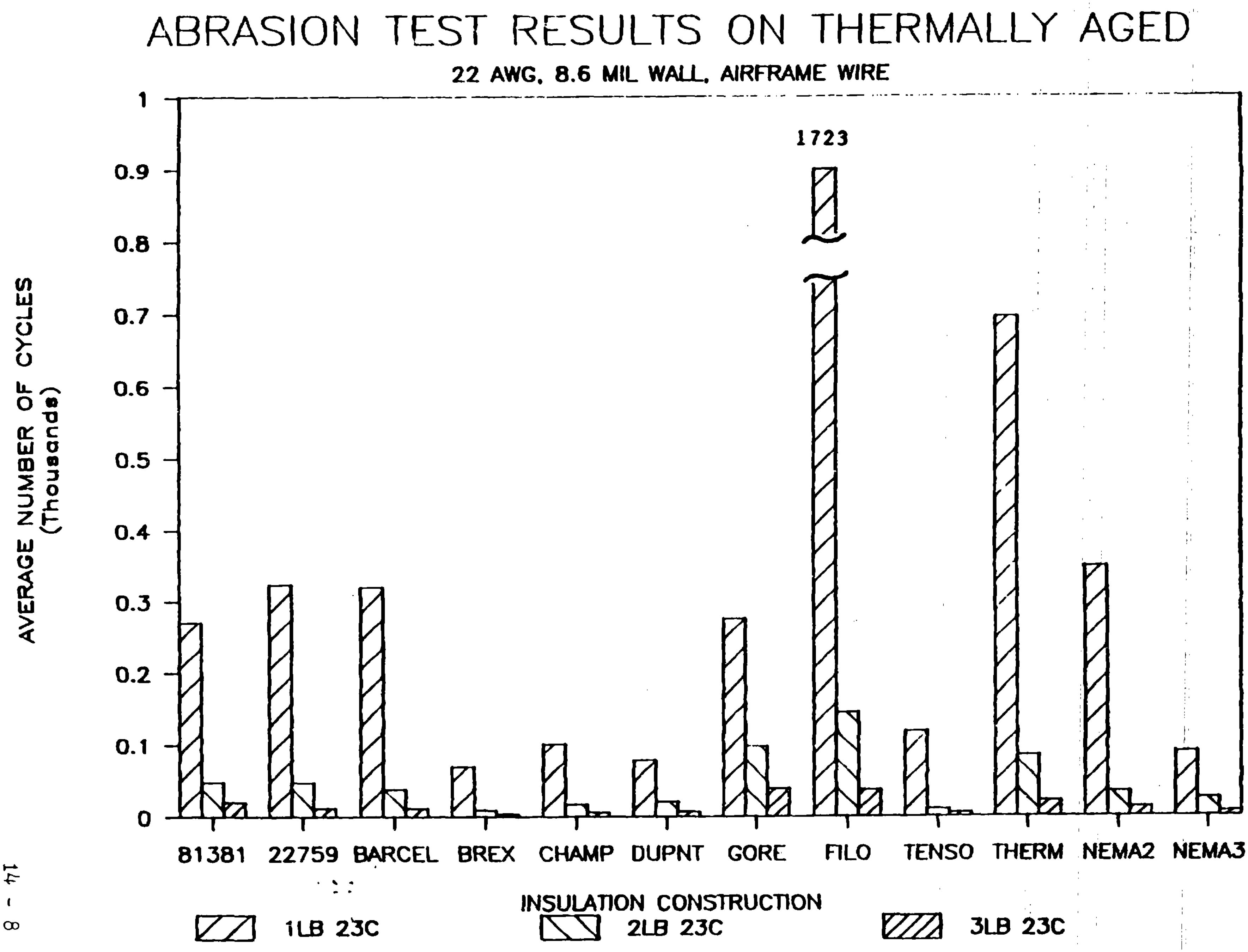


FIGURE 3.14 - ABRASION TEST RESULTS ON THERMALLY AGED, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 23°C

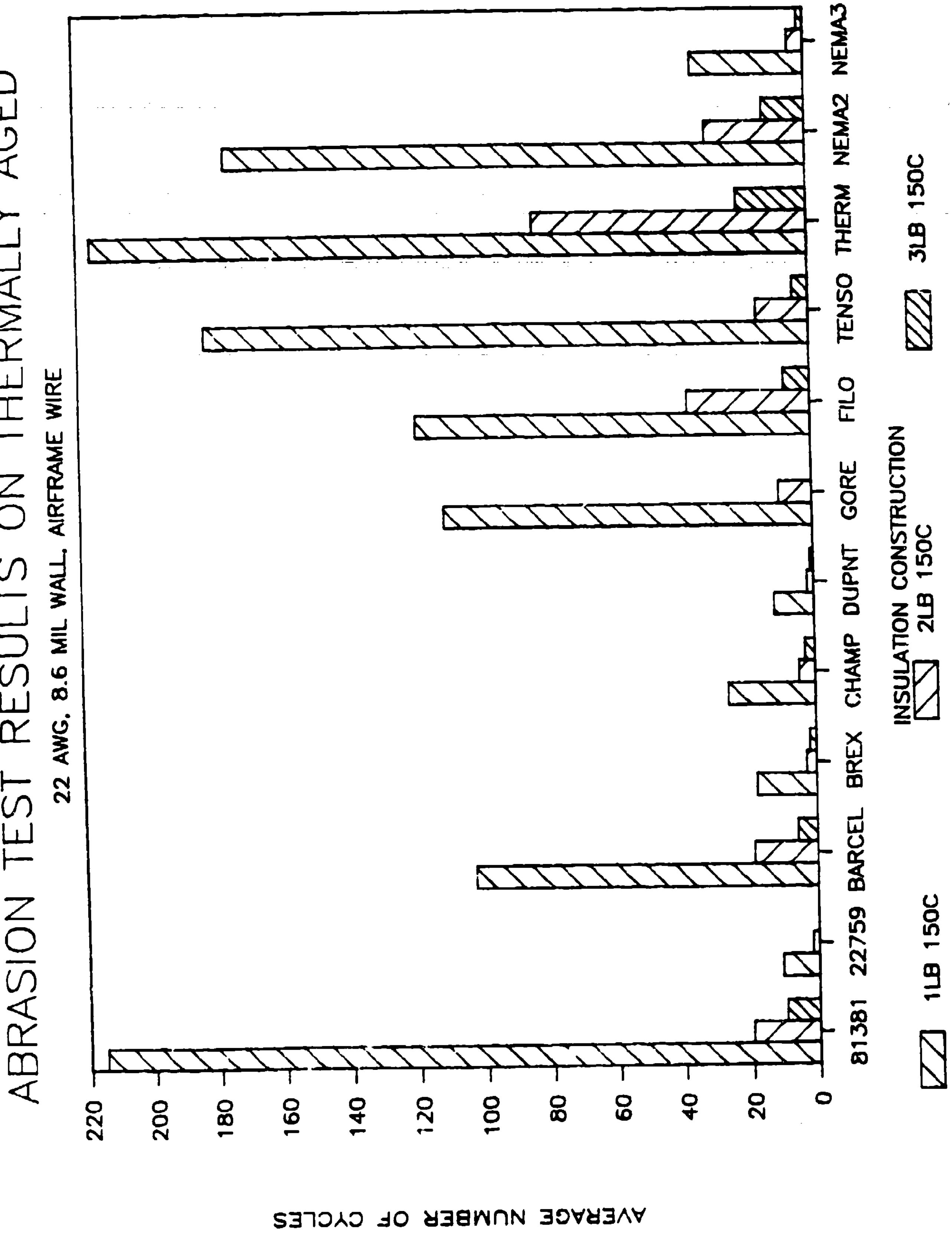


FIGURE 3.15 - ABRASION TEST RESULTS ON THERMALLY AGED, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 150°C

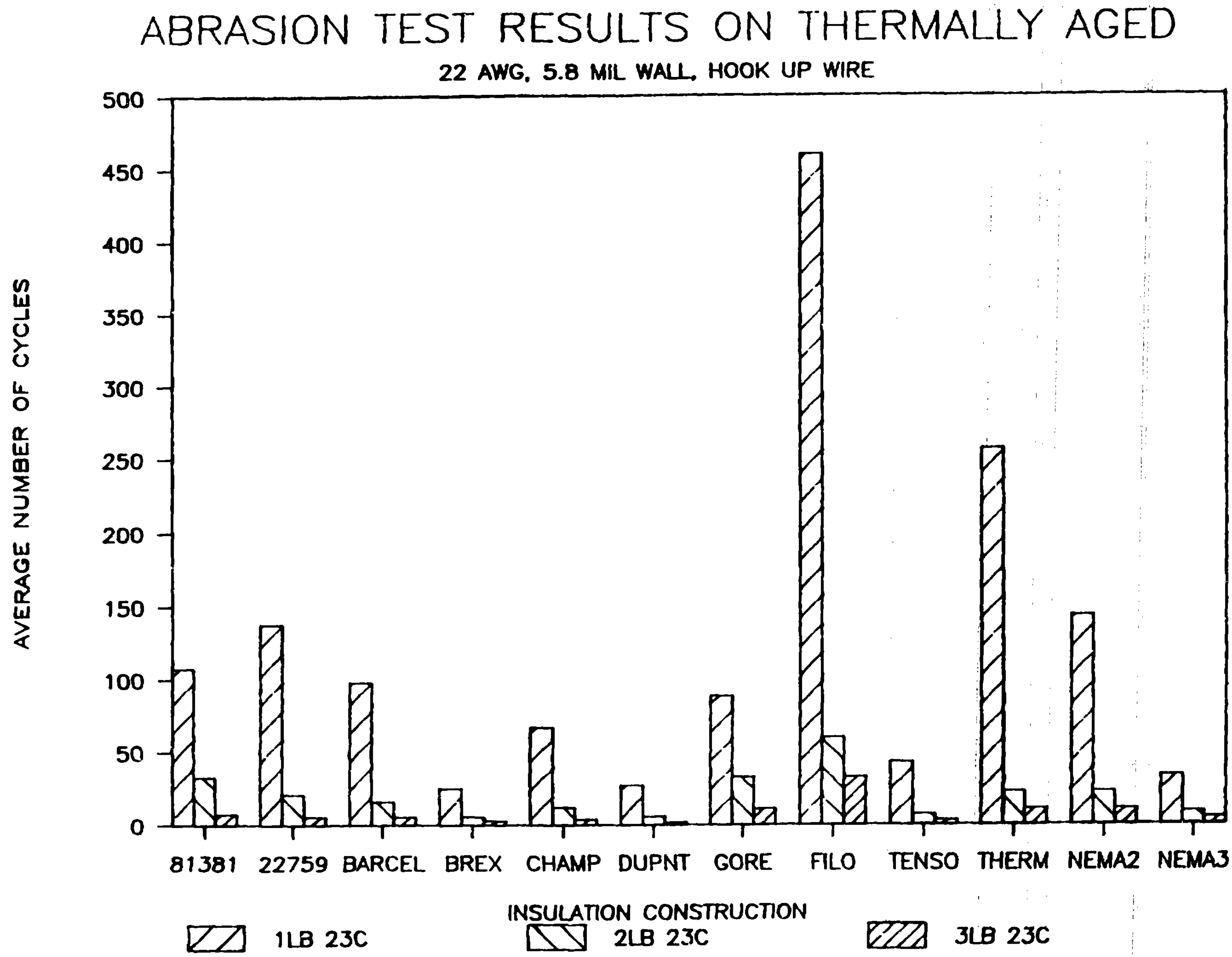


FIGURE 3.16 - ABRASION TEST RESULTS ON THERMALLY AGED, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 23°C

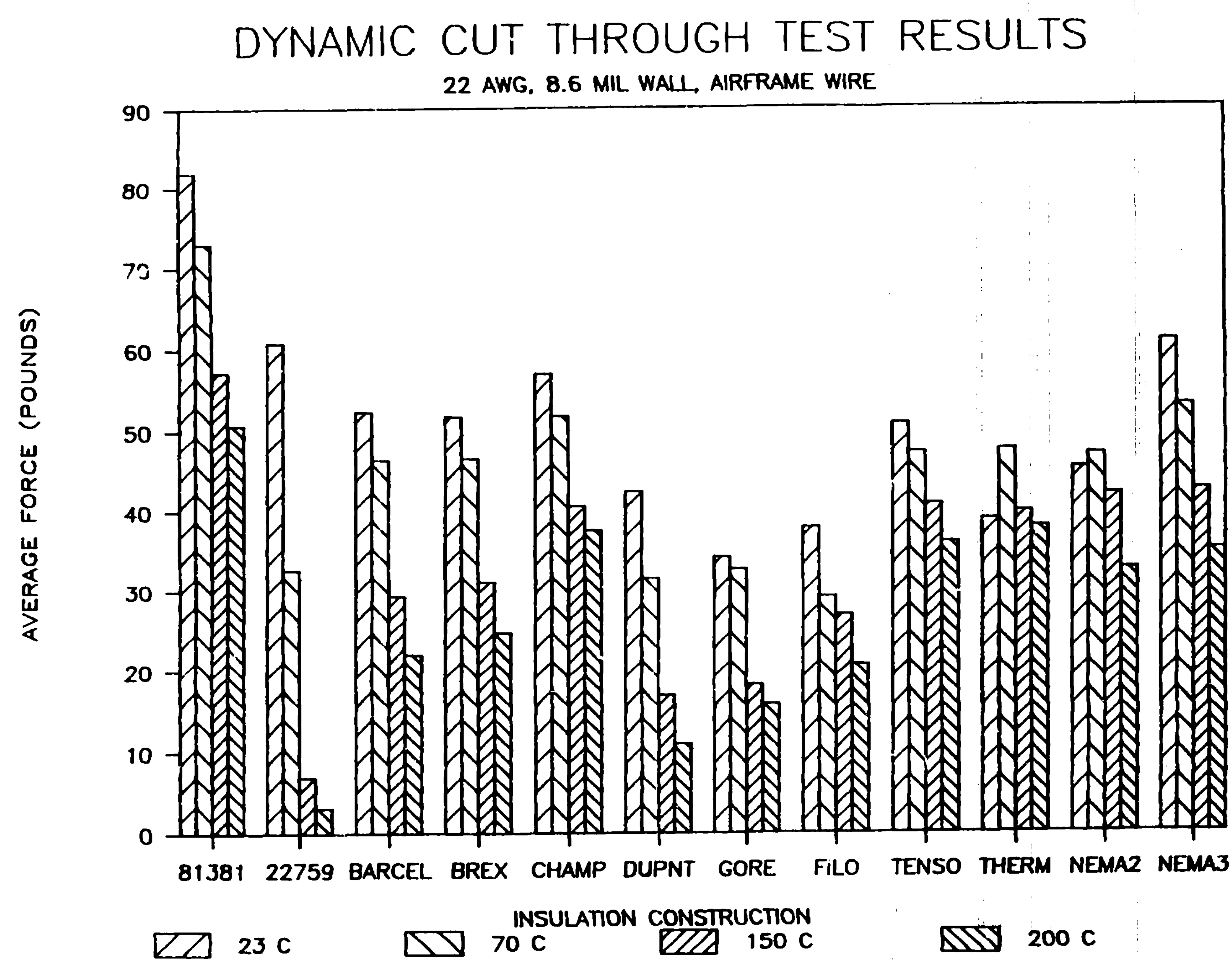


FIGURE 3.22 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

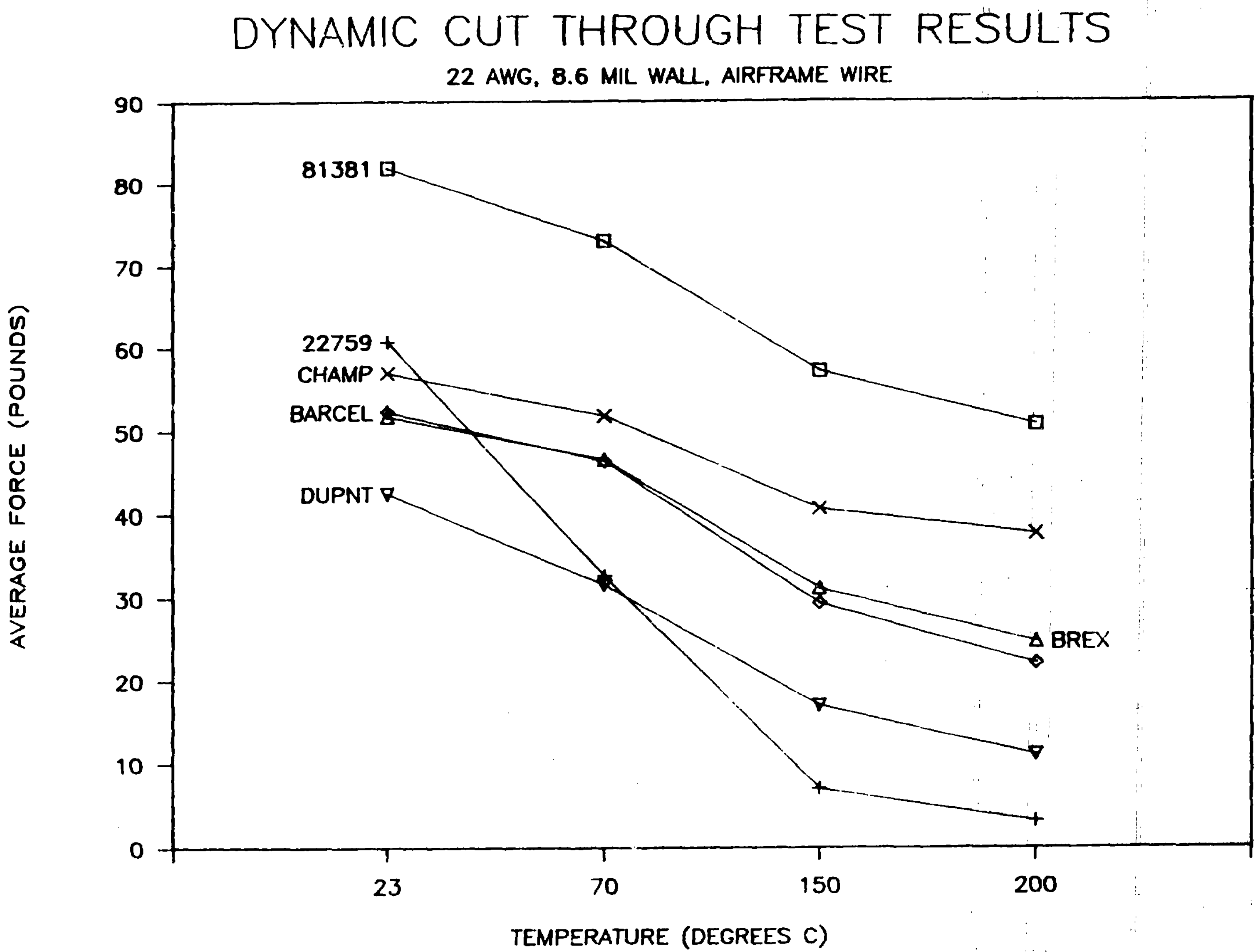


FIGURE 3.23 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

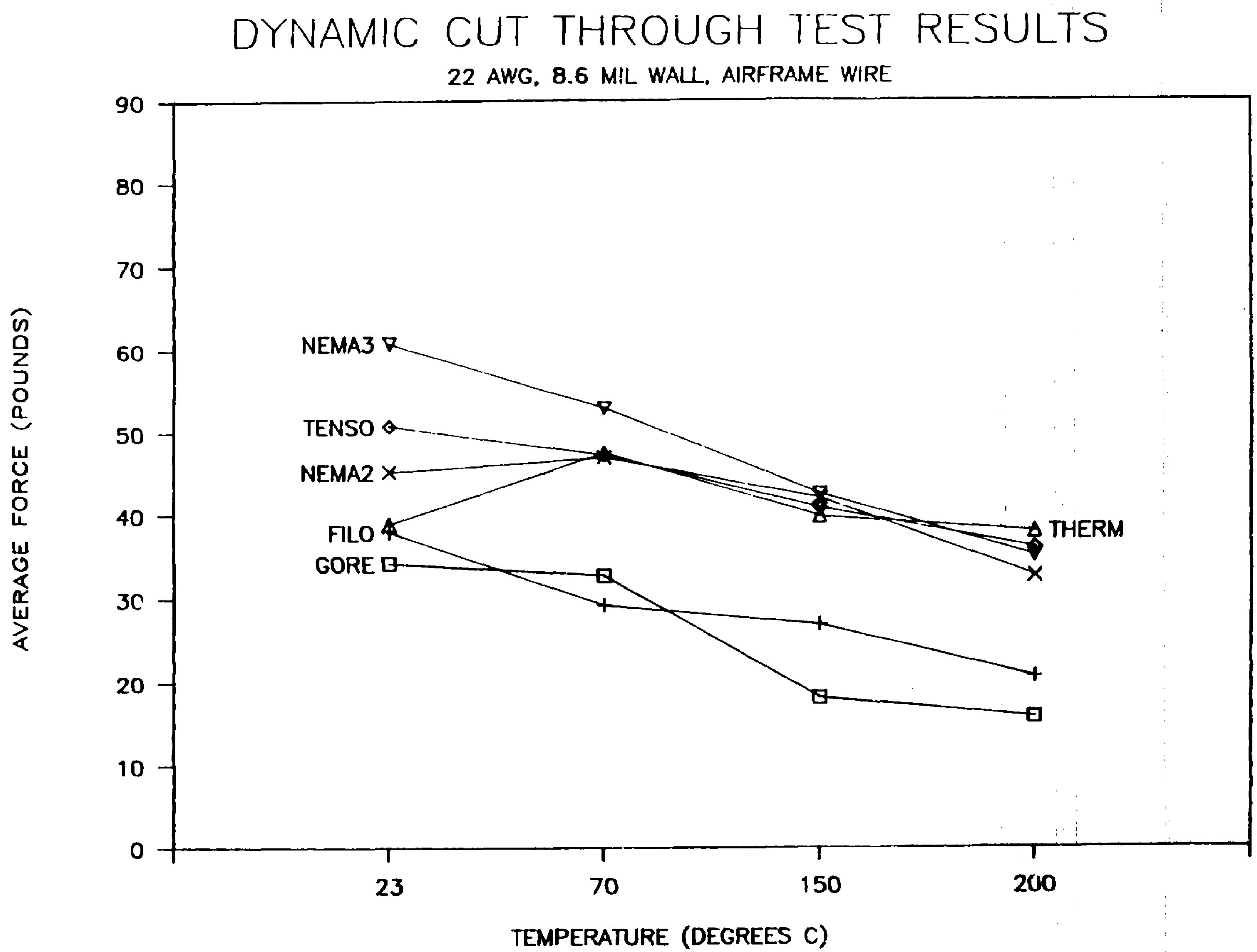


FIGURE 3.23 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE (Cont.)

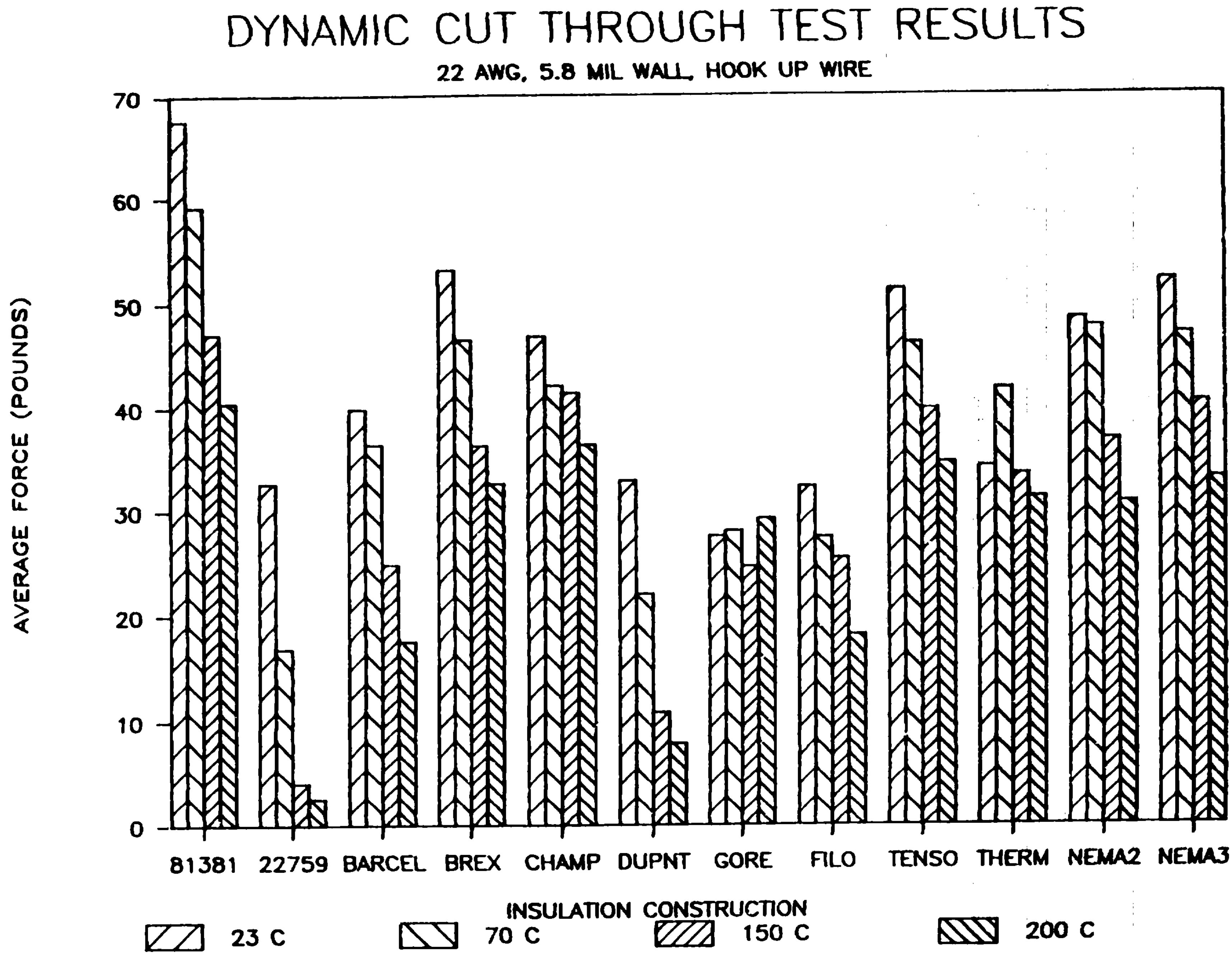


FIGURE 3.24 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

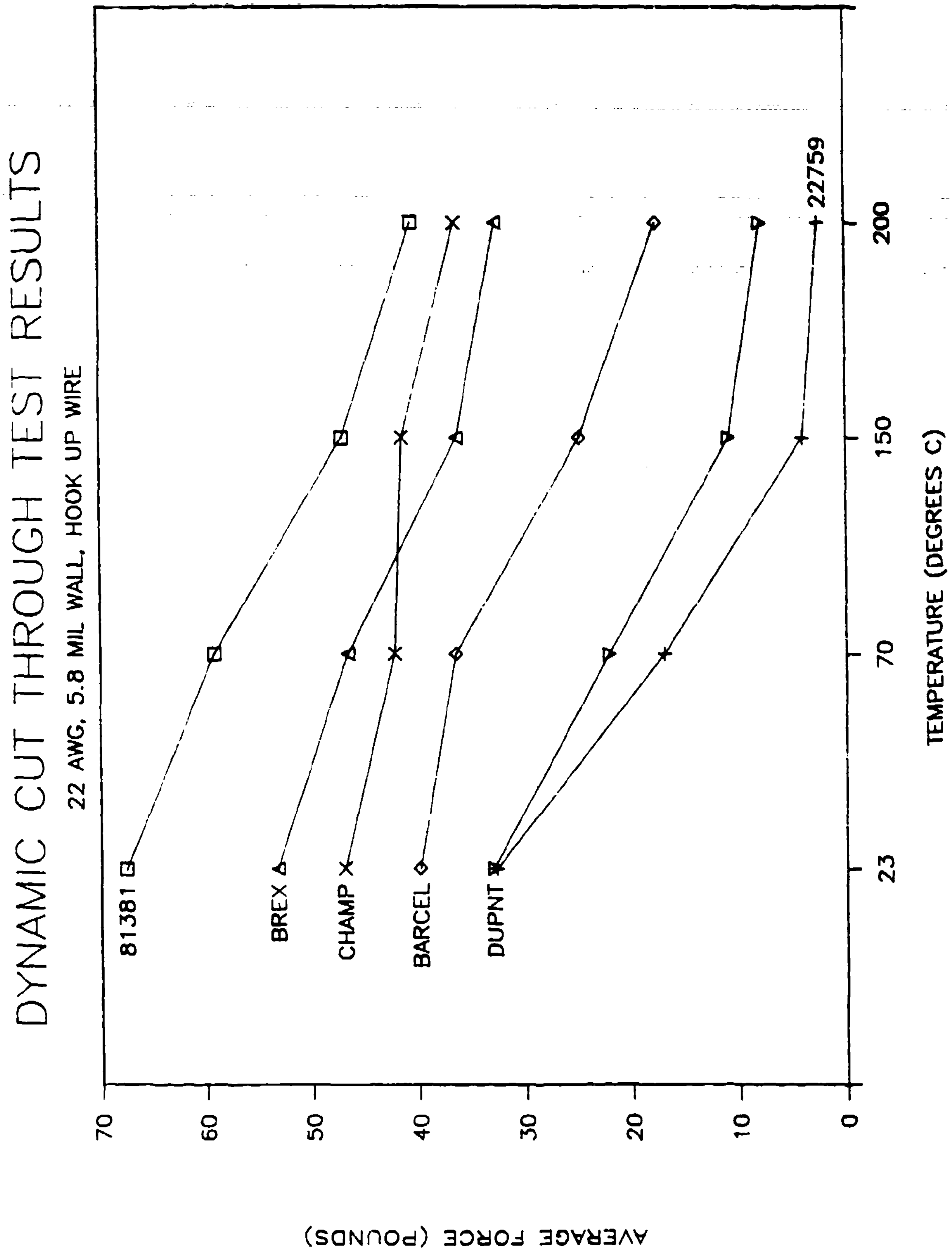


FIGURE 3.25 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

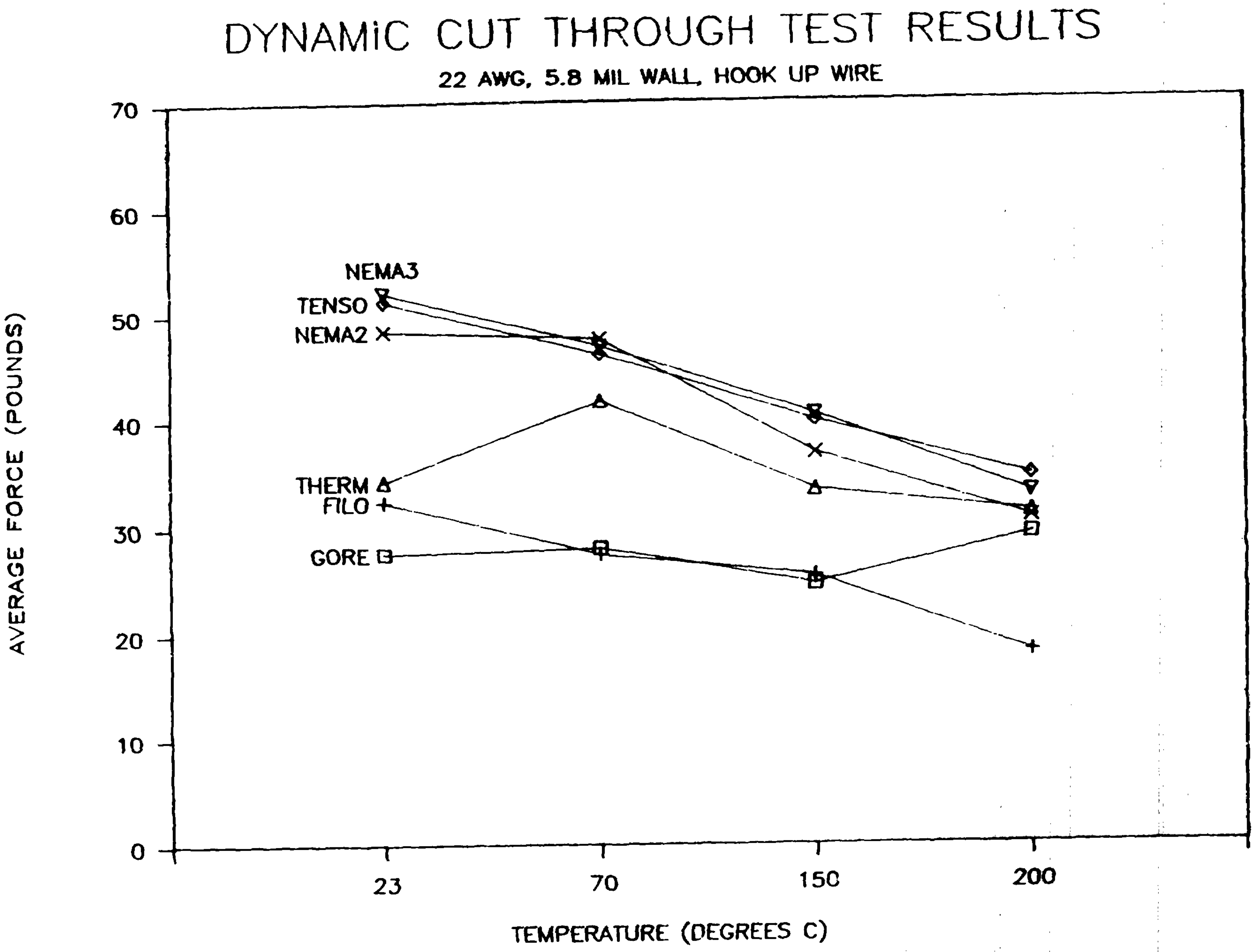


FIGURE 3.25 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE (Cont.)

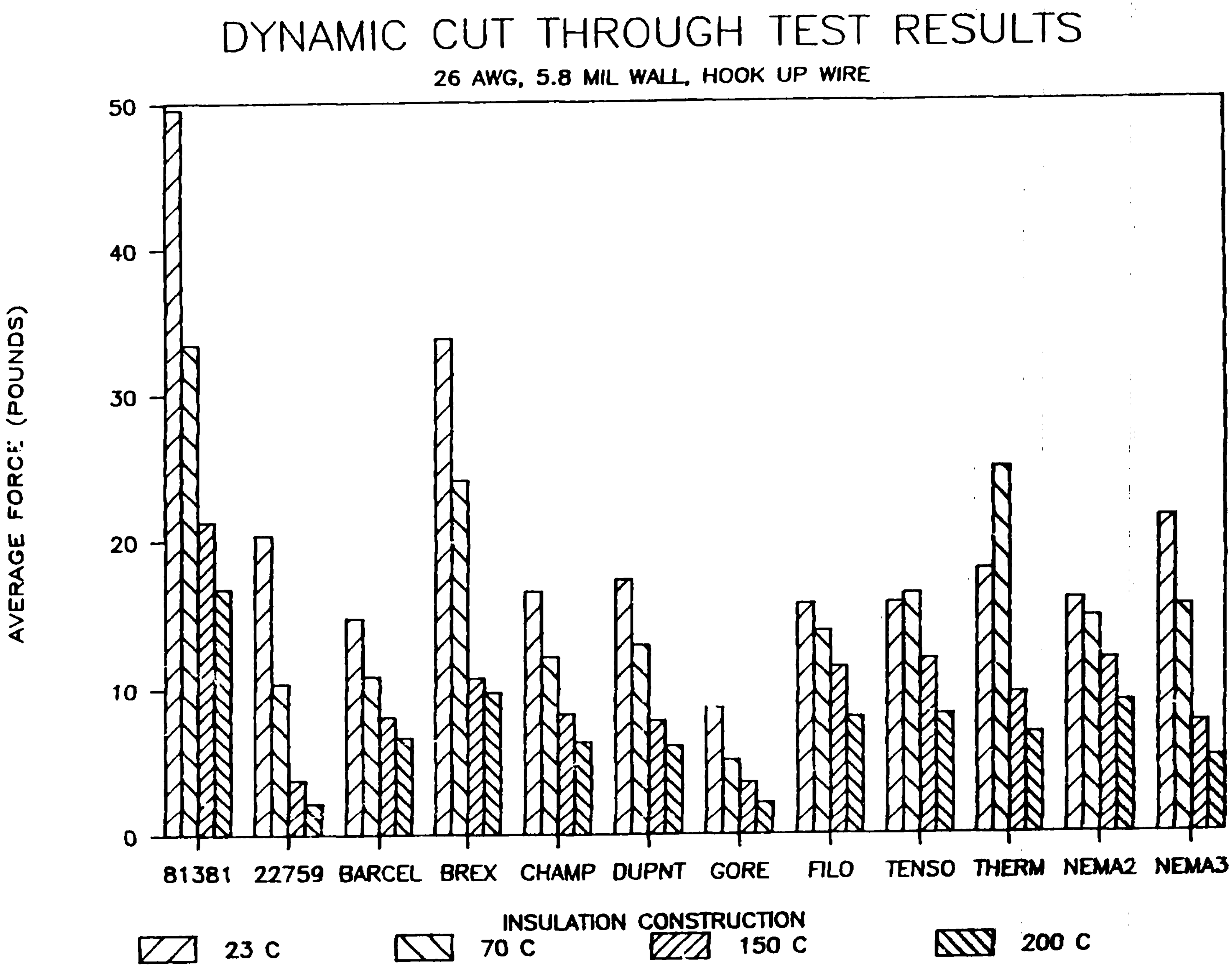


FIGURE 3.26 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

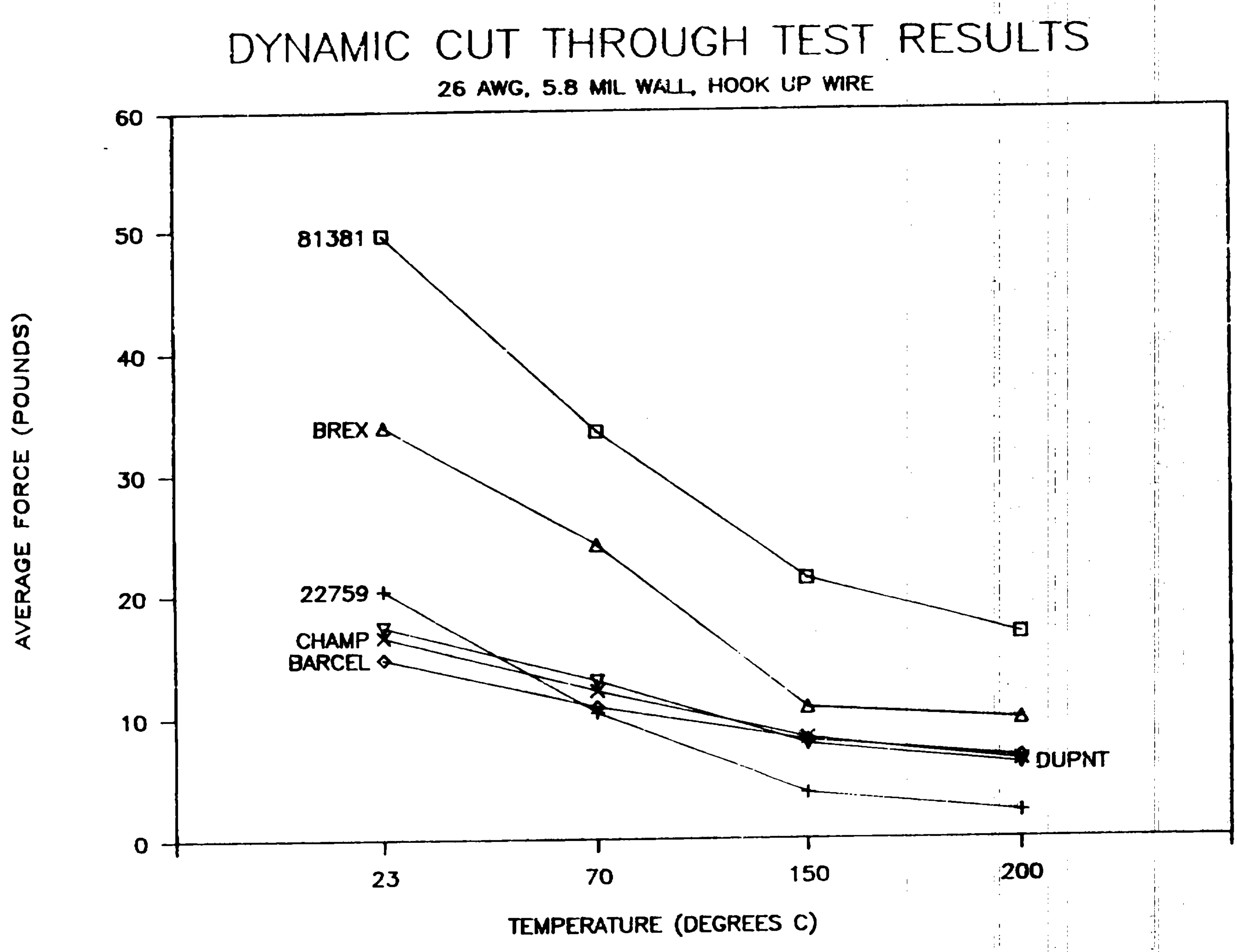


FIGURE 3.27 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

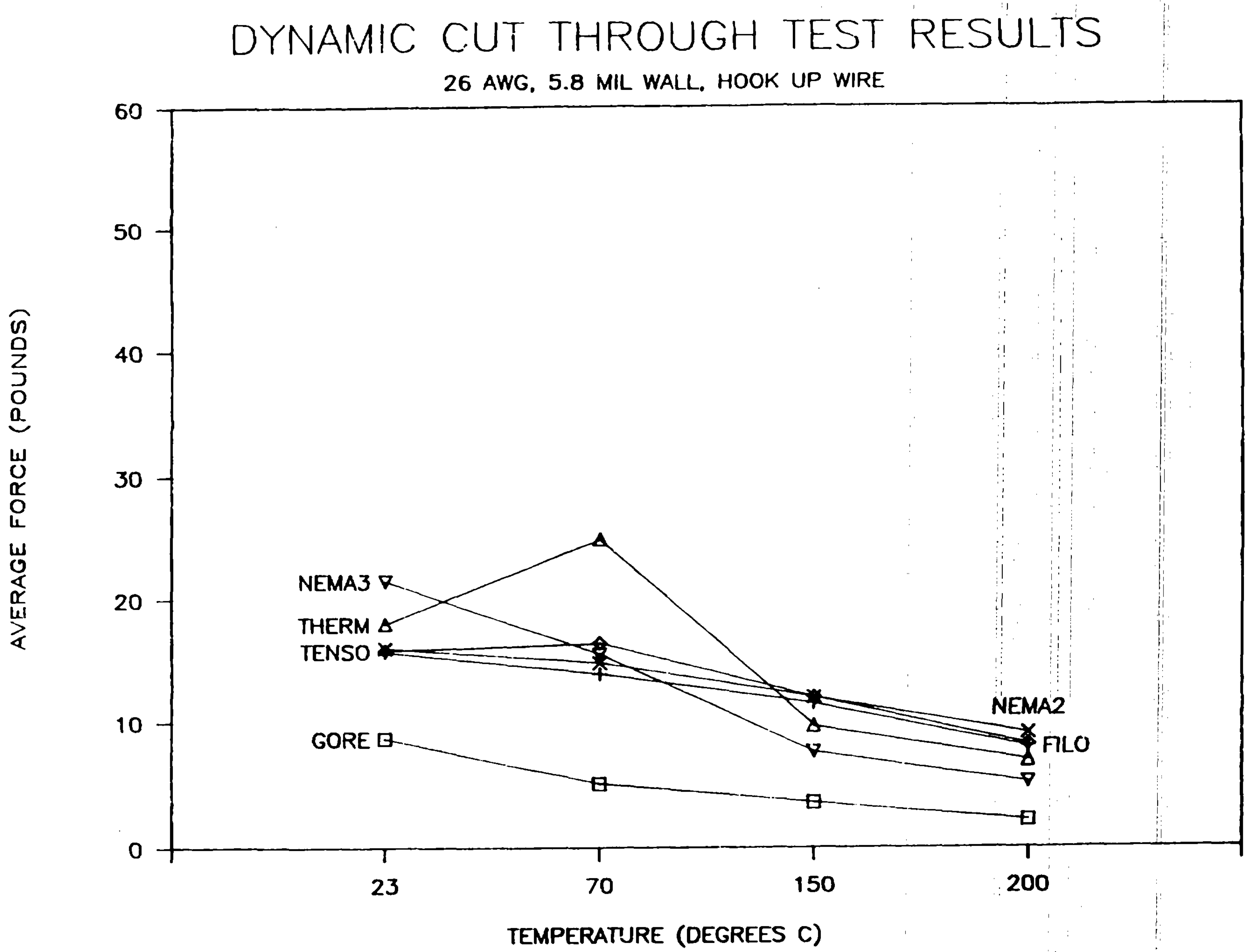


FIGURE 3.27 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE (Cont.)

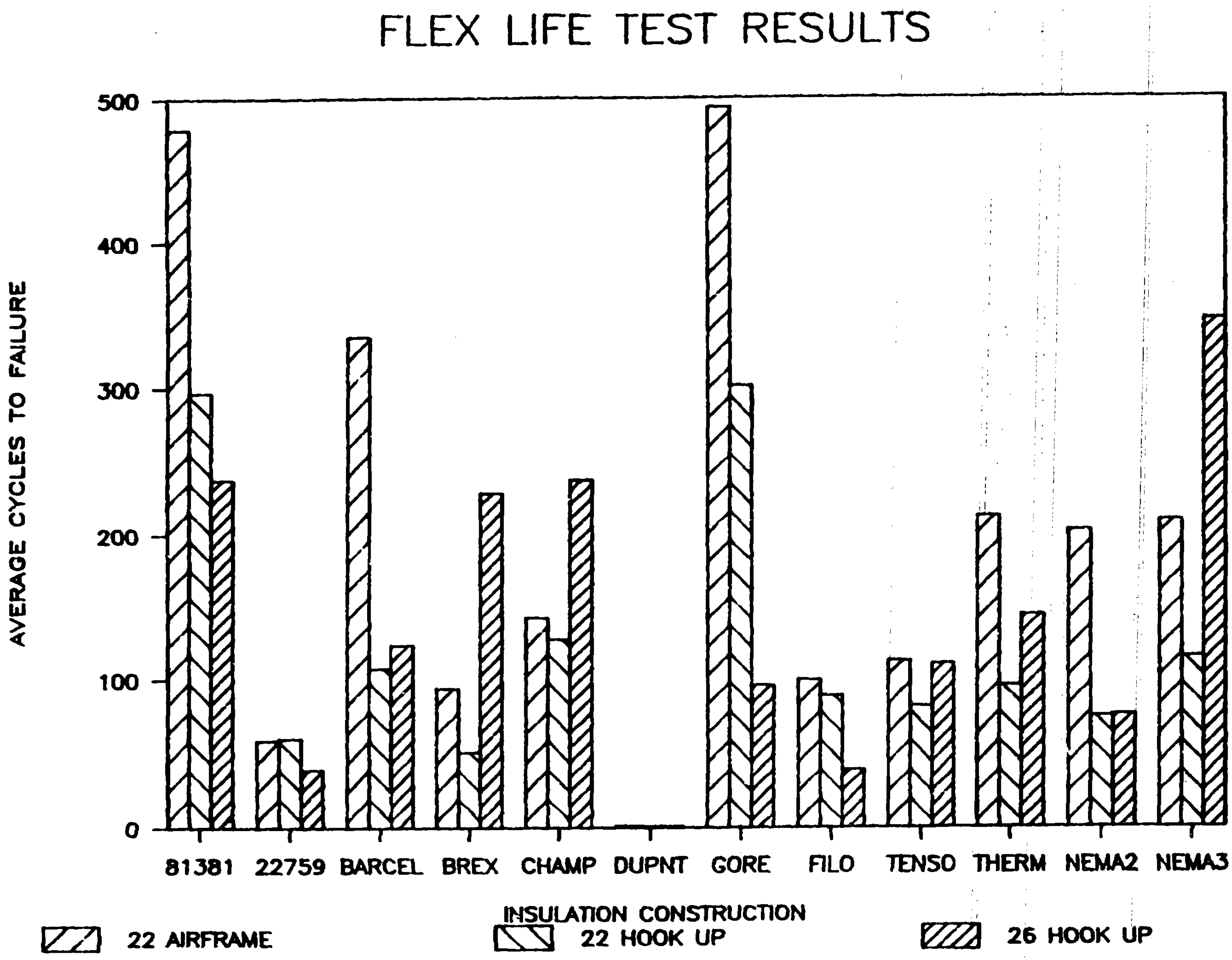


FIGURE 3.30 - FLEX LIFE TEST RESULTS

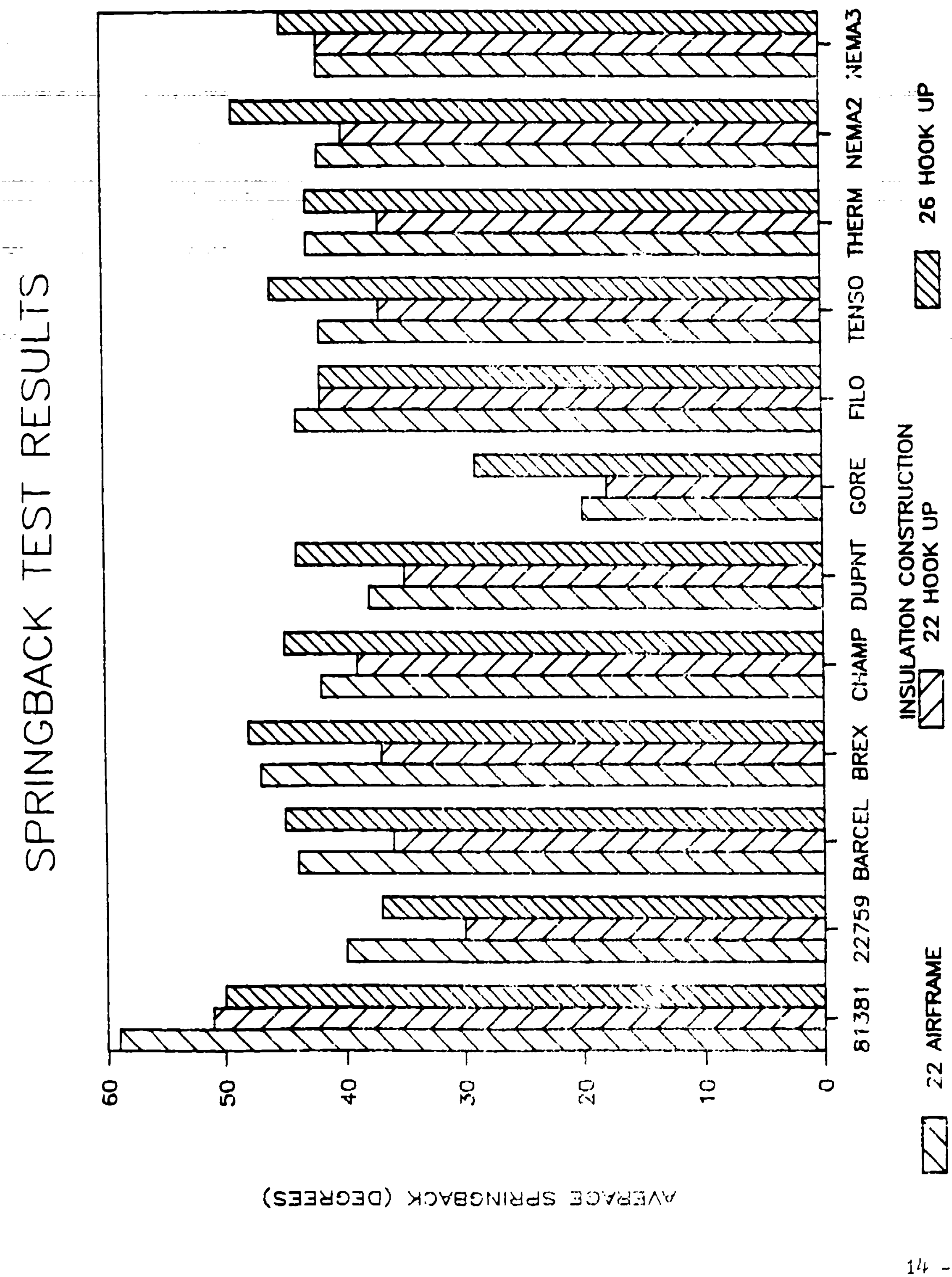


FIGURE 3.36 - SPRINGBACK TEST RESULTS

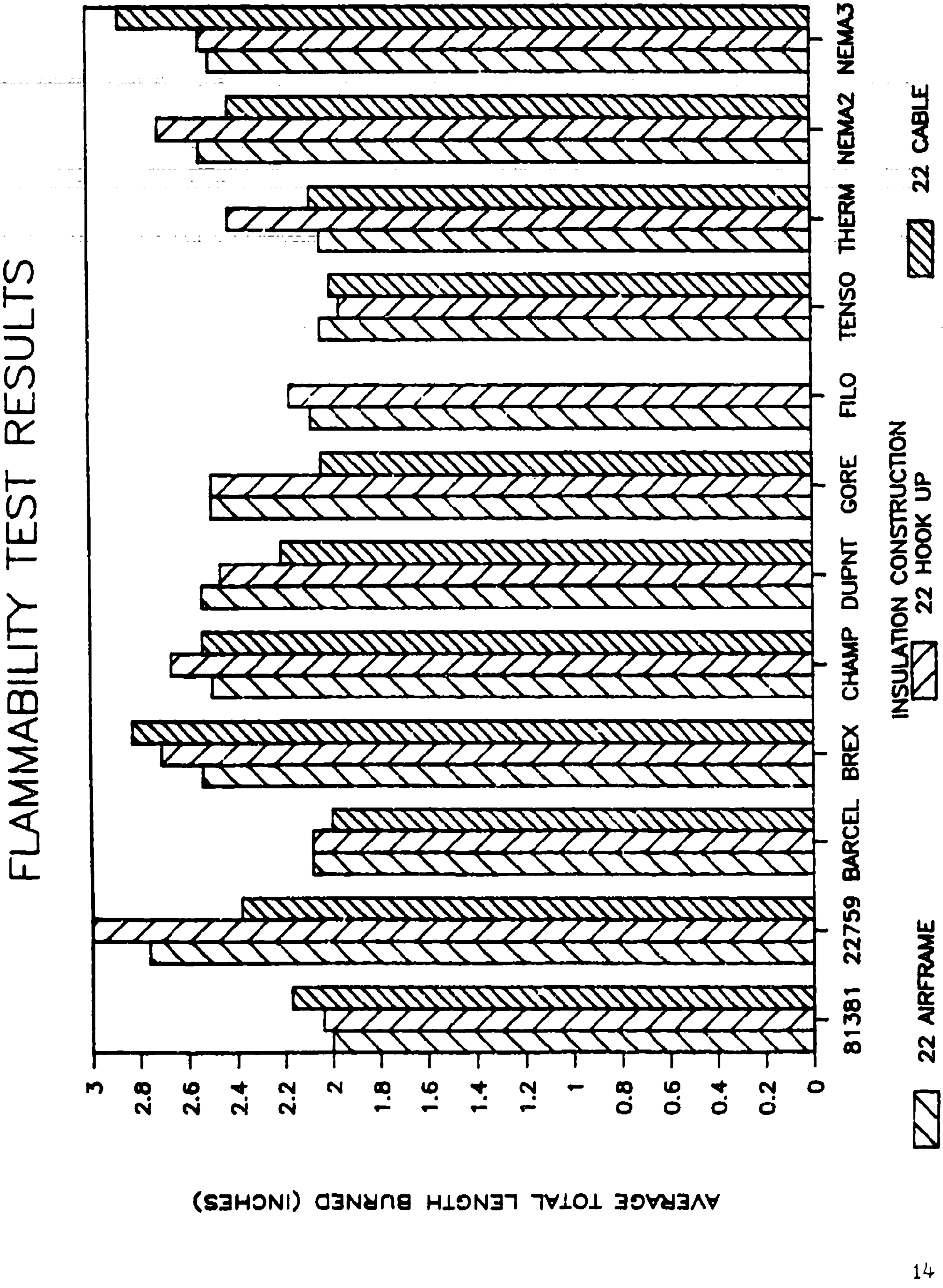


FIGURE 3.38 - FLAMMABILITY TEST RESULTS

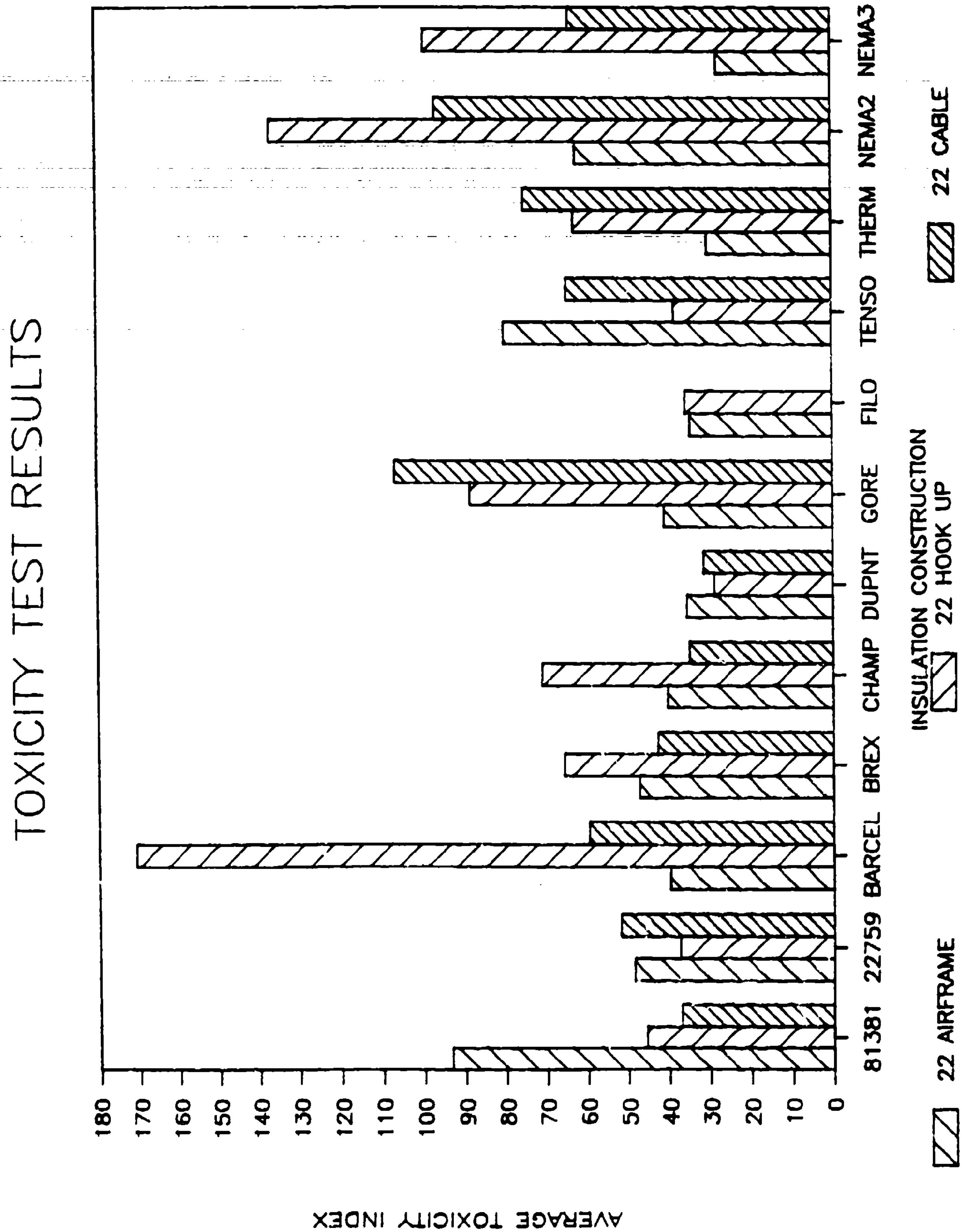


FIGURE 3.41 - TOXICITY TEST RESULTS

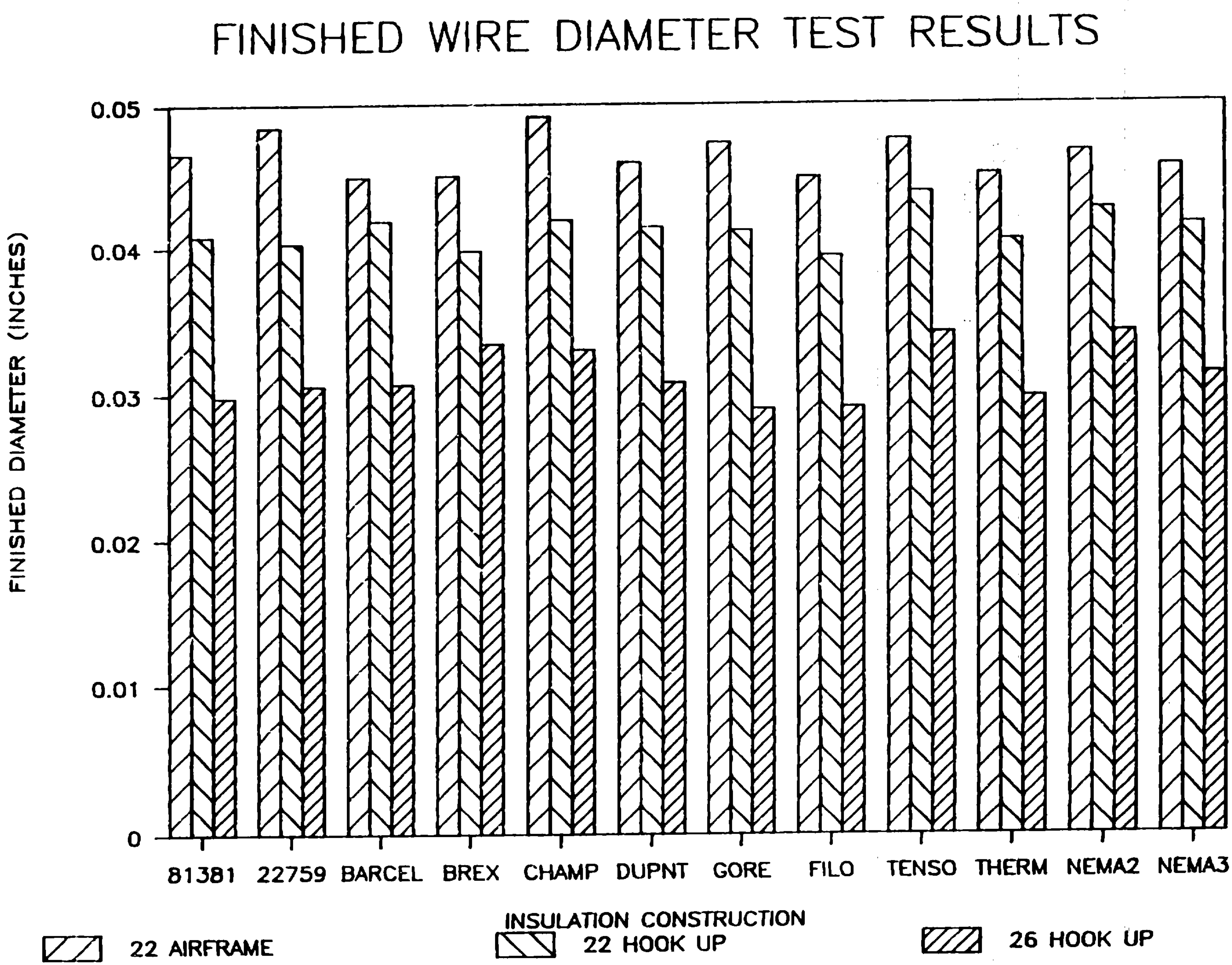


FIGURE 3.45 - FINISHED WIRE DIAMETER TEST RESULTS

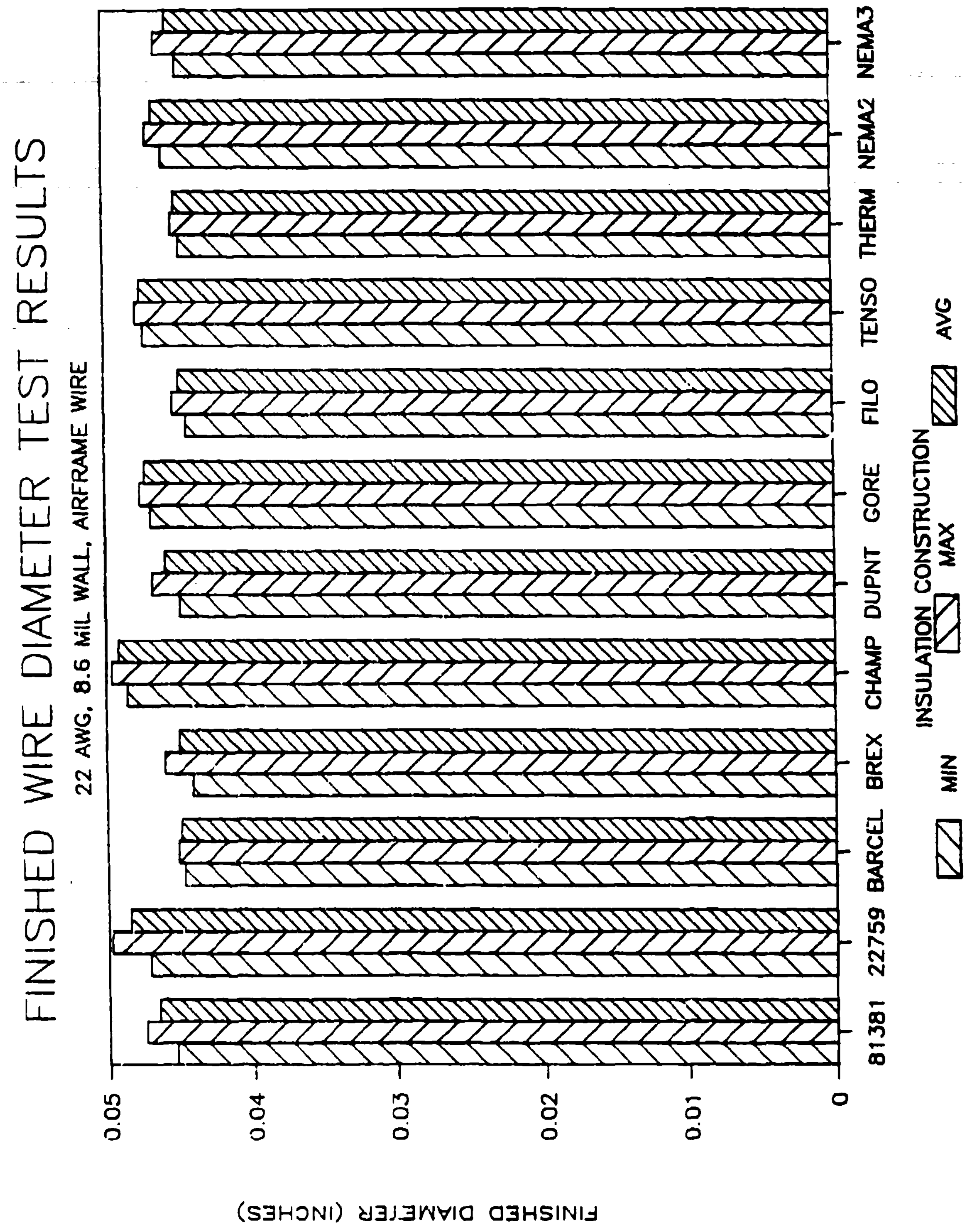


FIGURE 3.46 - FINISHED WIRE DIAMETER TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

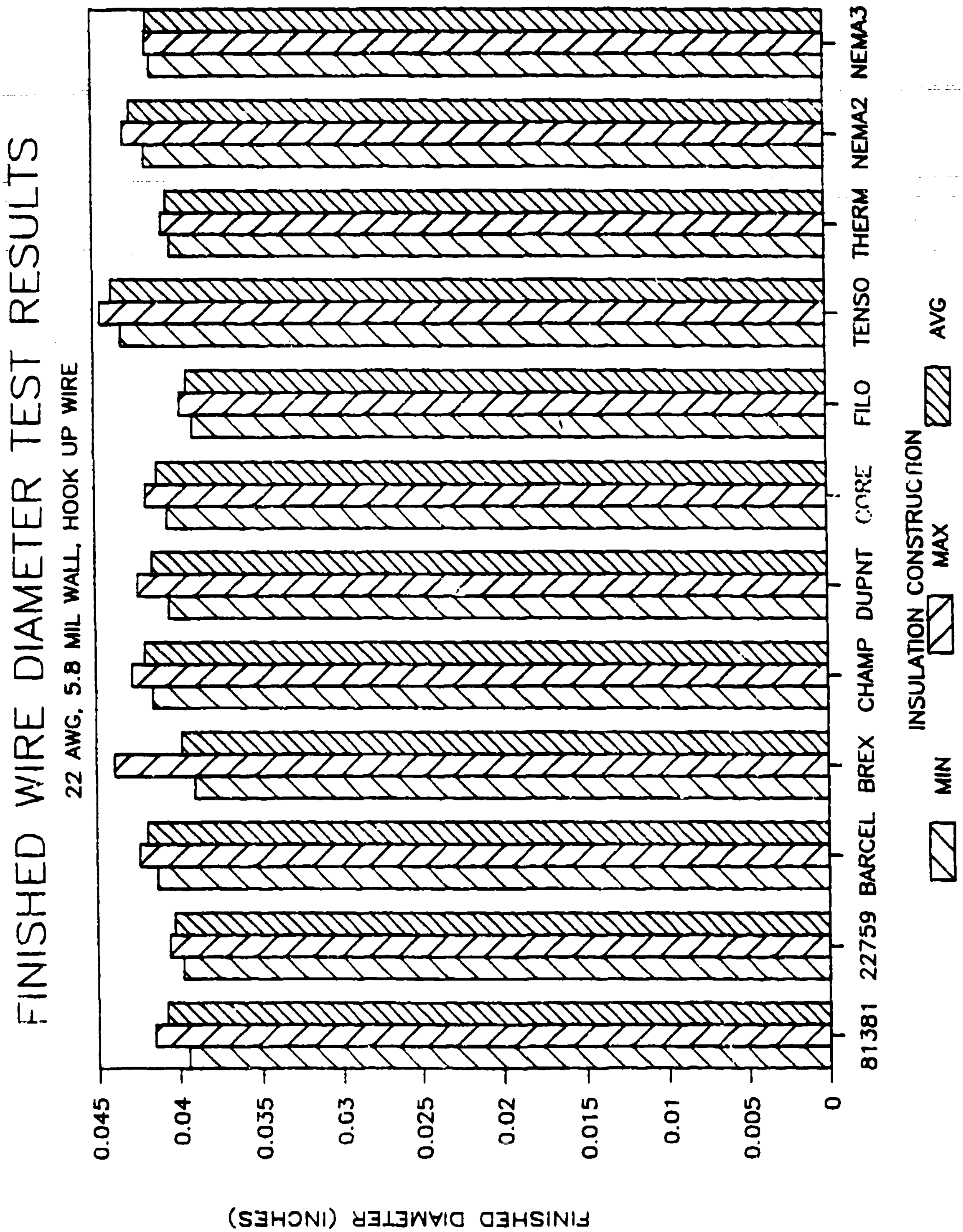


FIGURE 3.47 - FINISHED WIRE DIAMETER TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

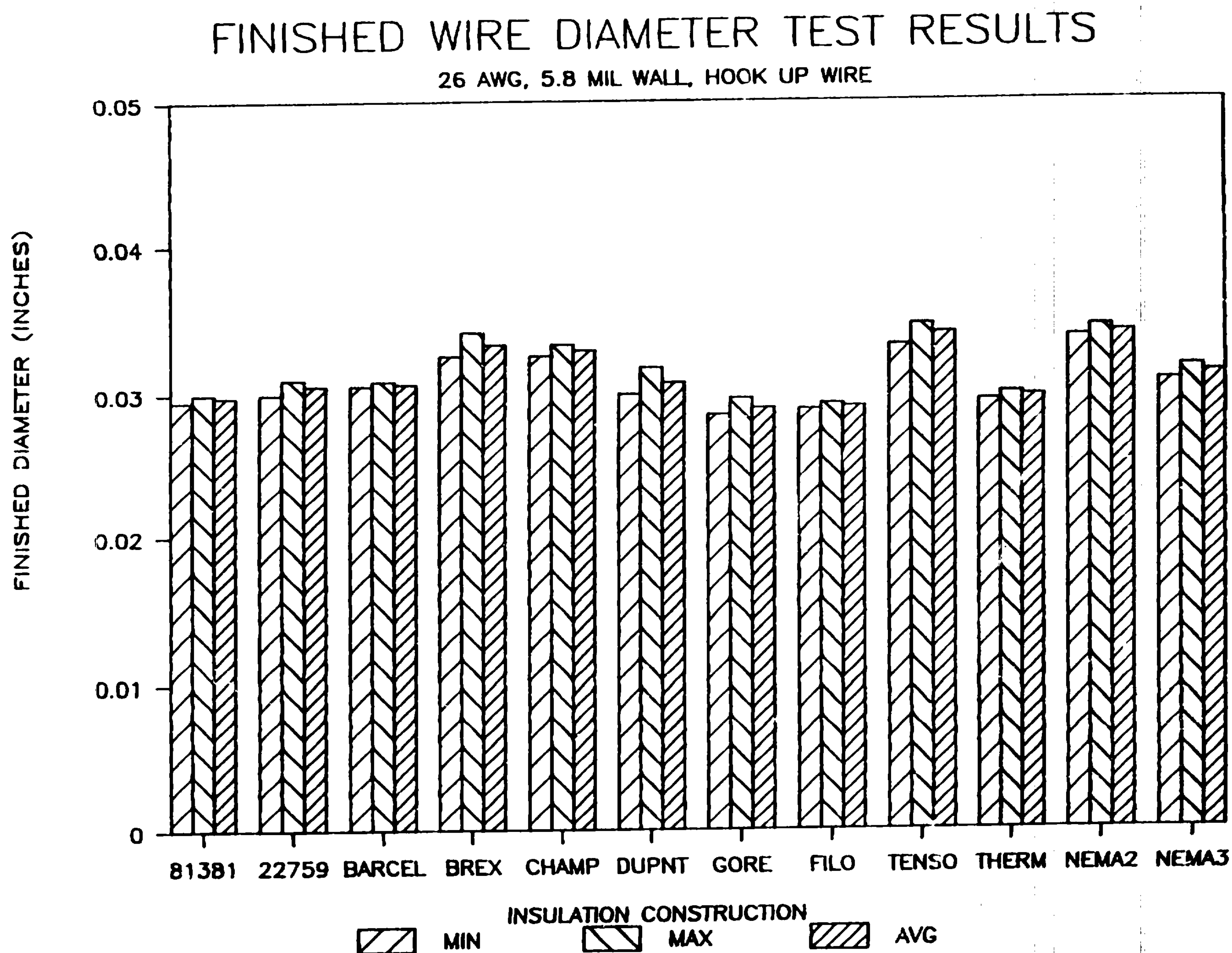


FIGURE 3.48 - FINISHED WIRE DIAMETER TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

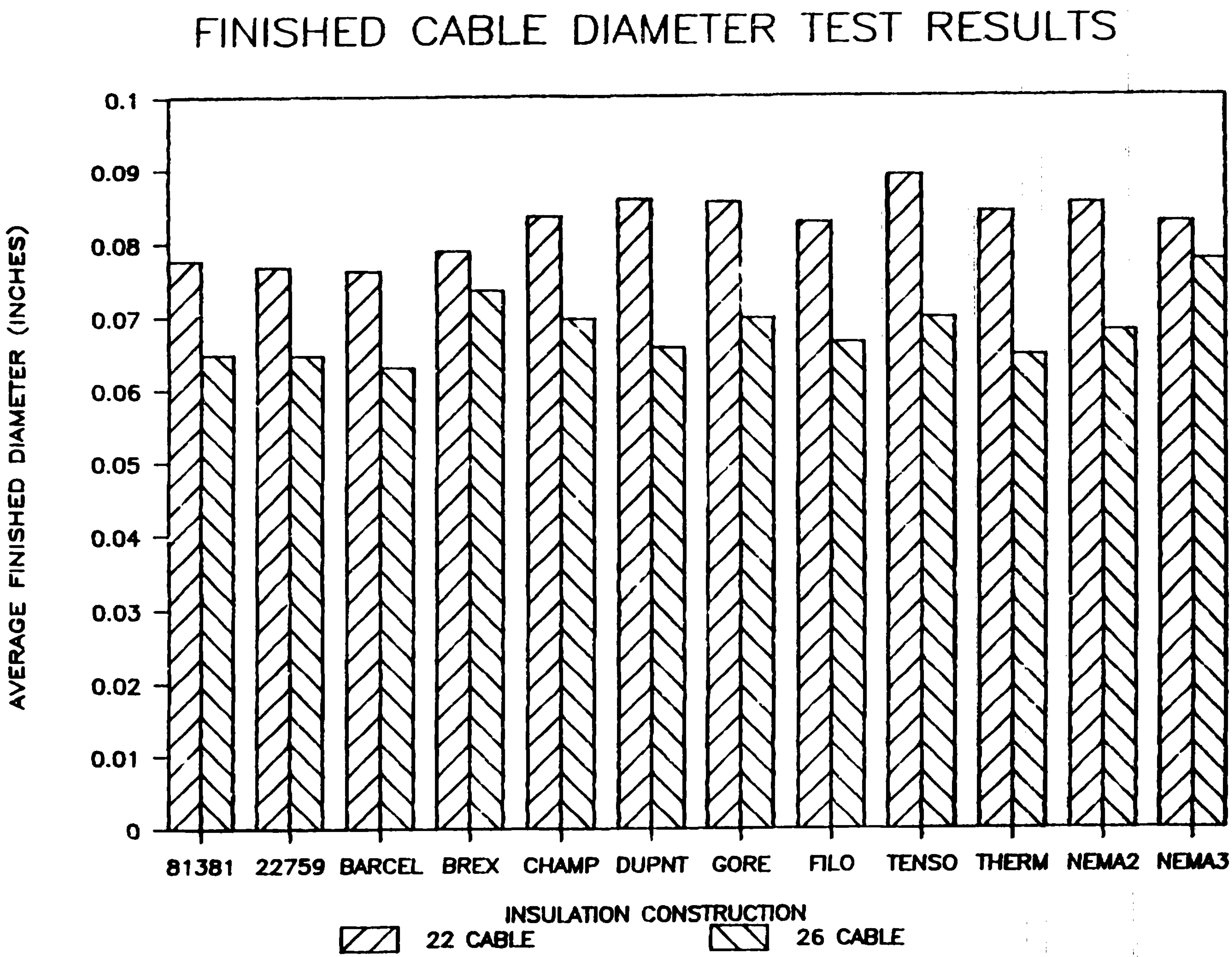


FIGURE 3.49 - FINISHED CABLE DIAMETER TEST RESULTS

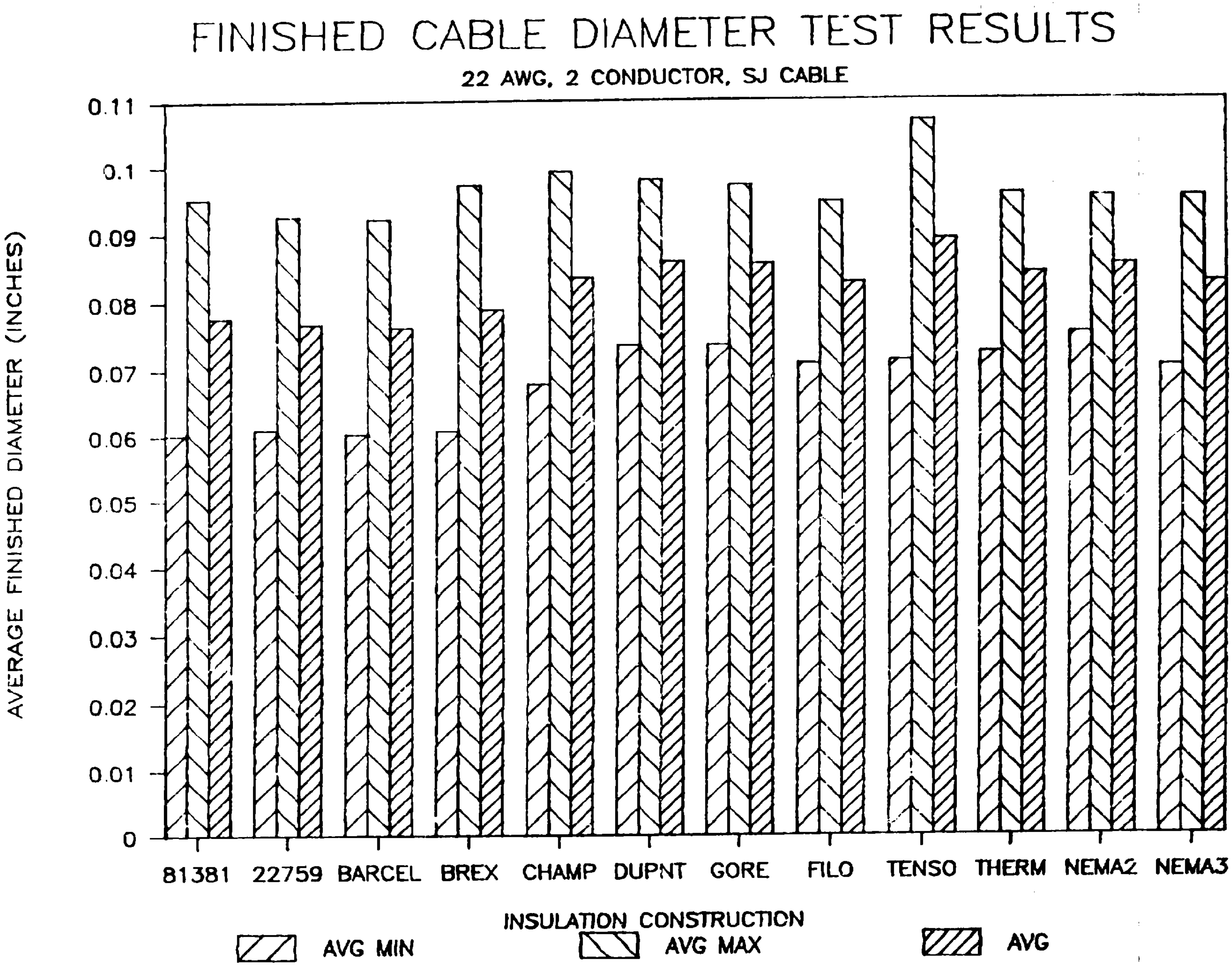


FIGURE 3.50 - FINISHED CABLE DIAMETER TEST RESULTS, 22AWG, 2 CONDUCTOR, SJ CABLE

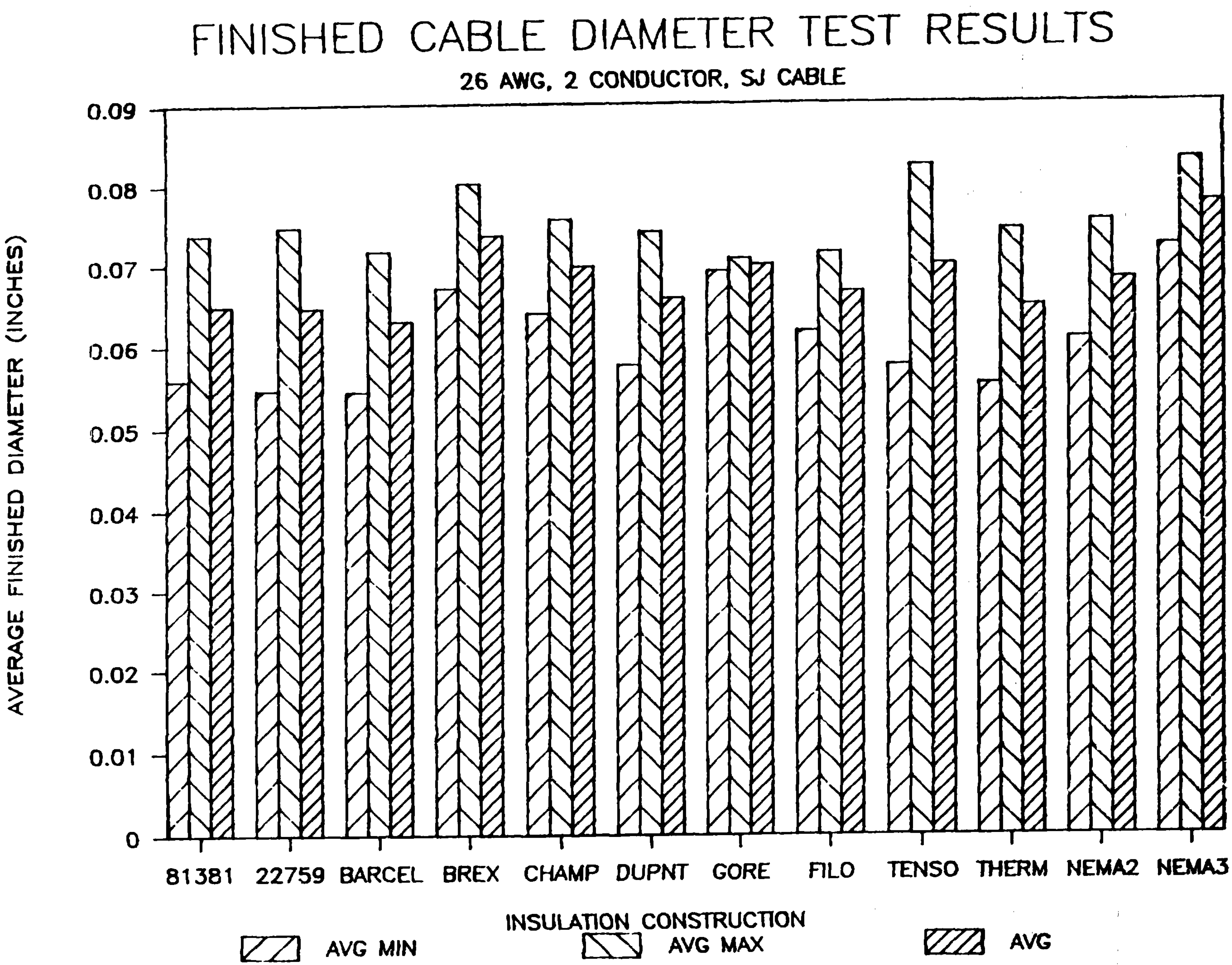


FIGURE 3.51 - FINISHED CABLE DIAMETER TEST RESULTS, 26AWG, 2 CONDUCTOR, SJ CABLE

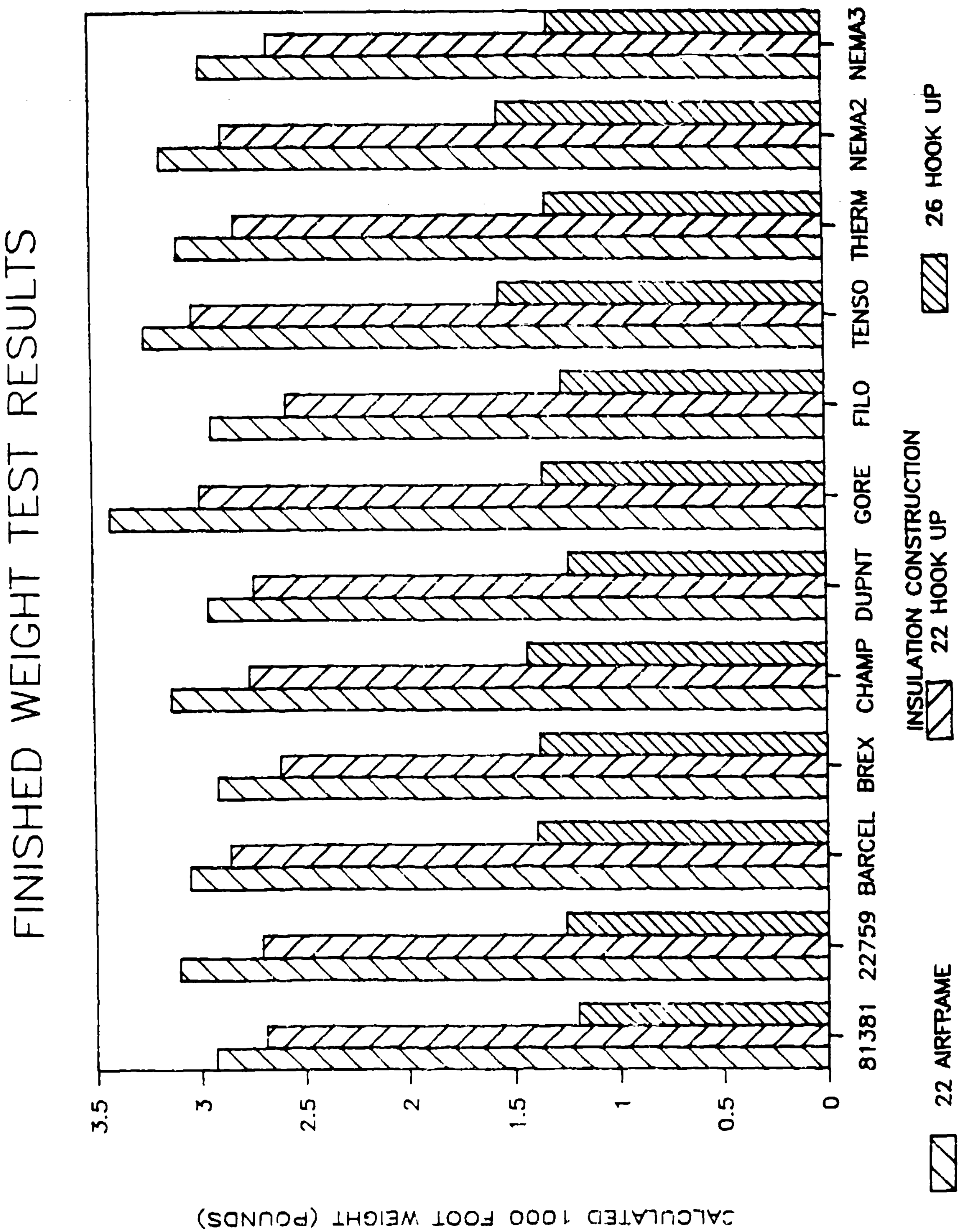


FIGURE 3.52 - FINISHED WEIGHT TEST RESULTS

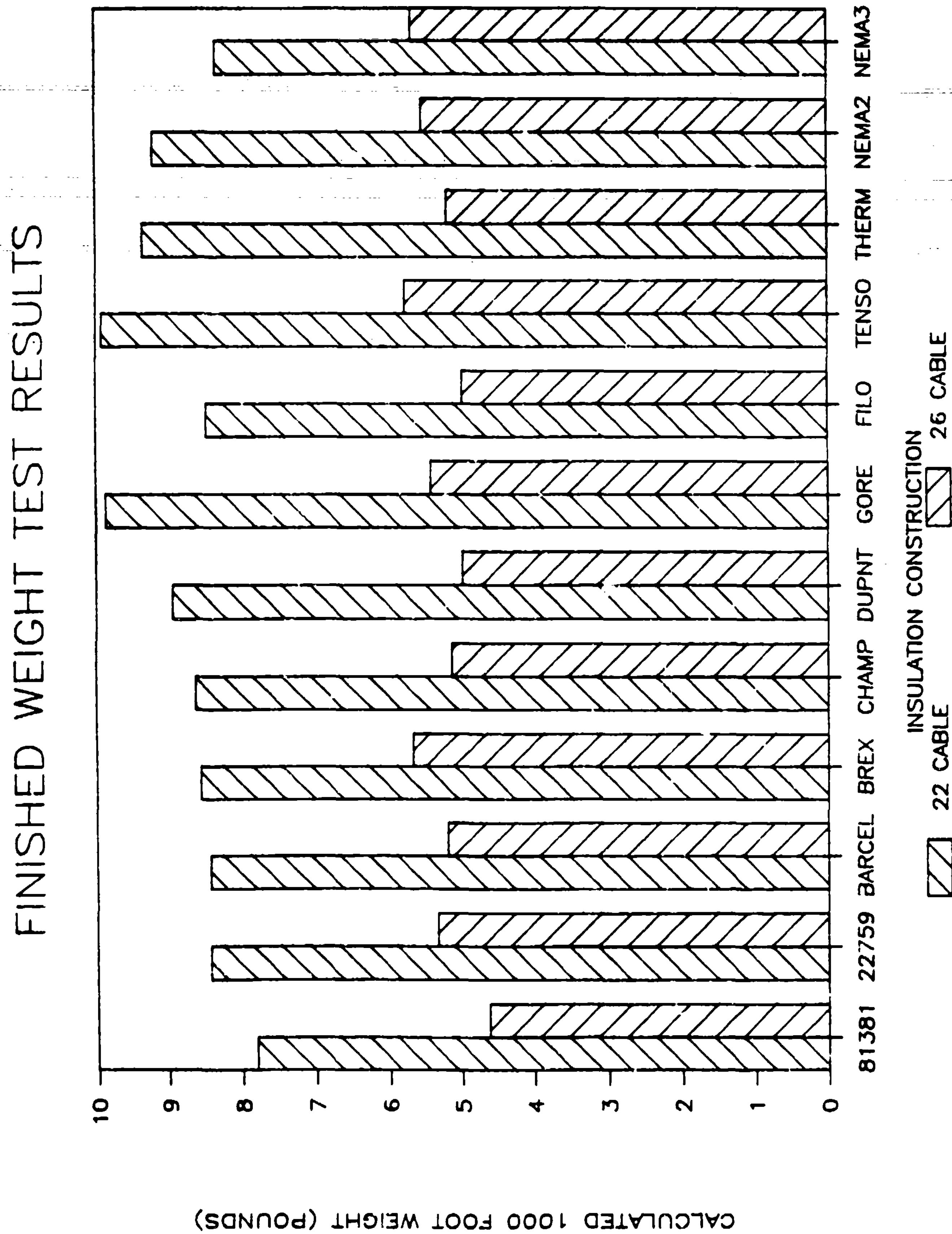


FIGURE 3.53 - FINISHED WEIGHT TEST RESULTS

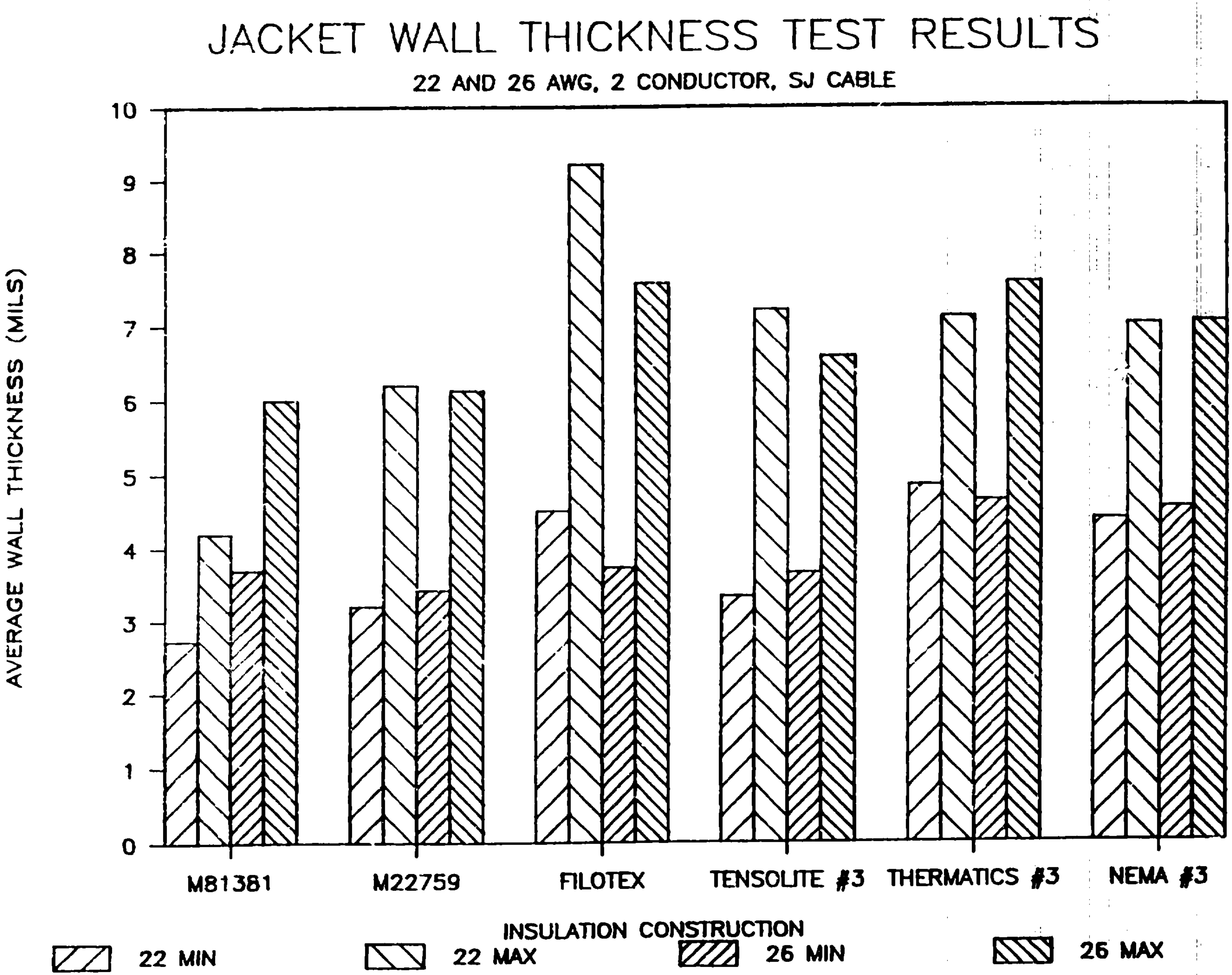


FIGURE 5.1 - JACKET WALL THICKNESS TEST RESULTS

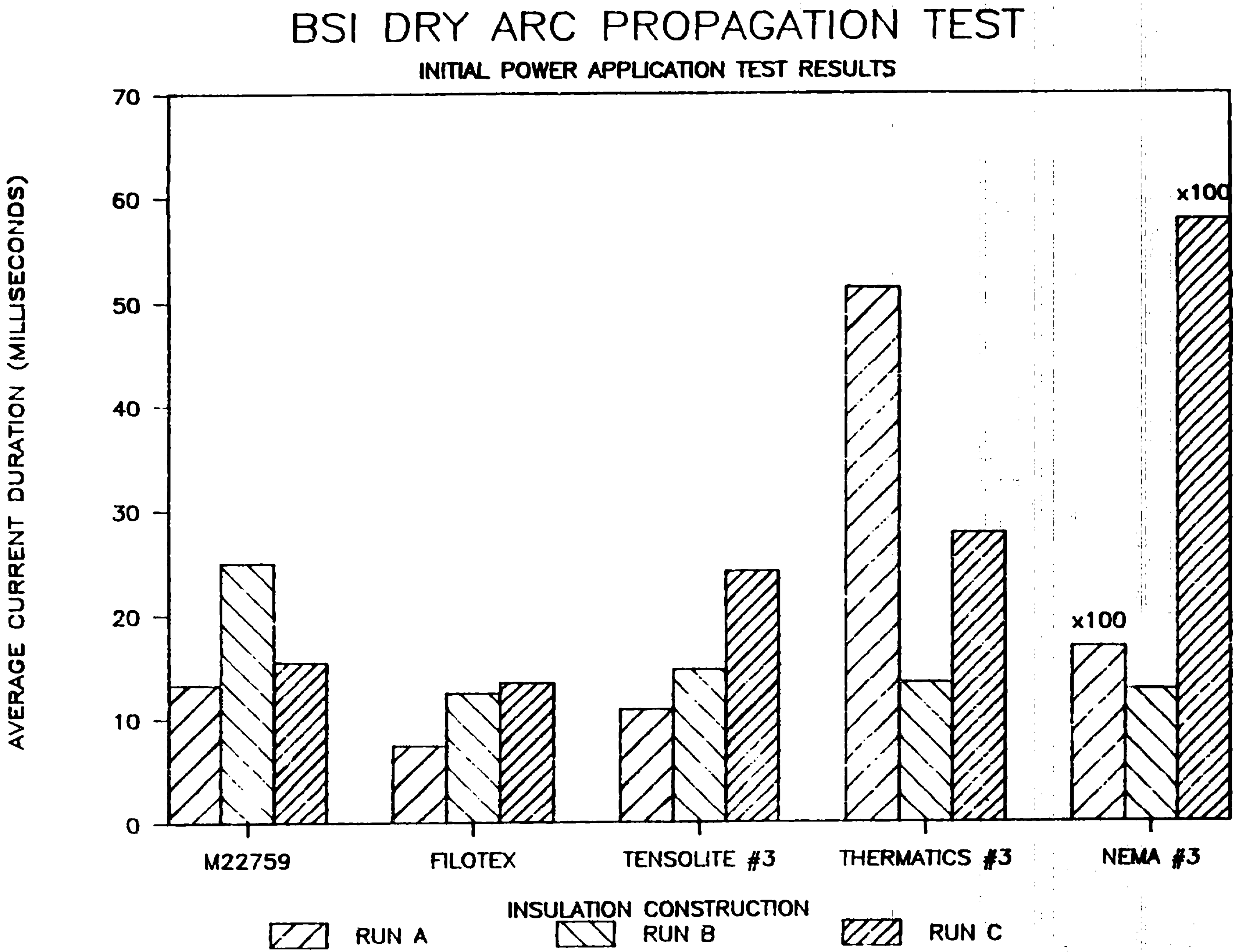


FIGURE 5.3 - BSI DRY ARC PROPAGATION TEST, INITIAL POWER APPLICATION TEST RESULTS

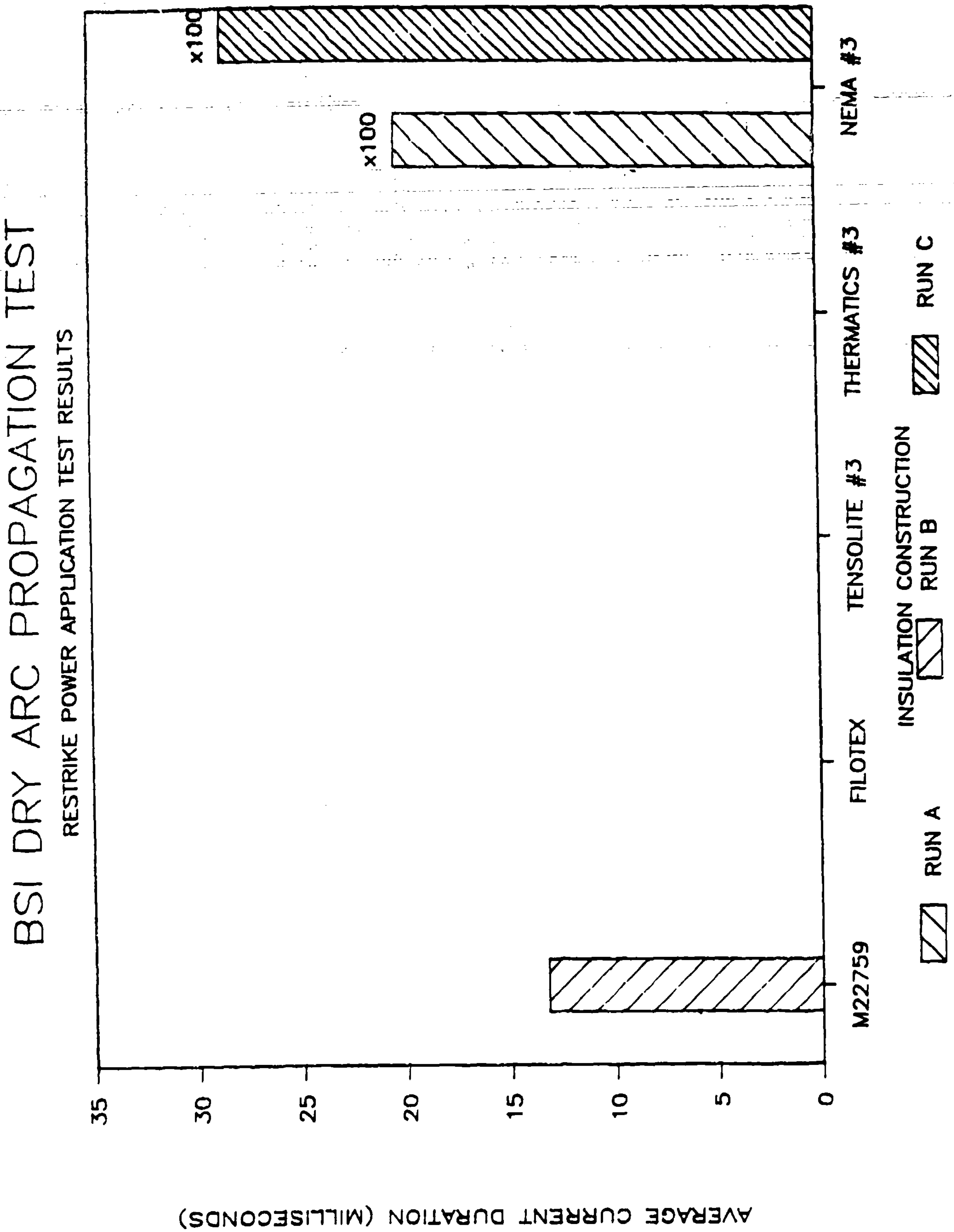


FIGURE 5.4 - BSI DRY ARC PROPAGATION TEST,
RESTRIKE POWER APPLICATION TEST RESULTS

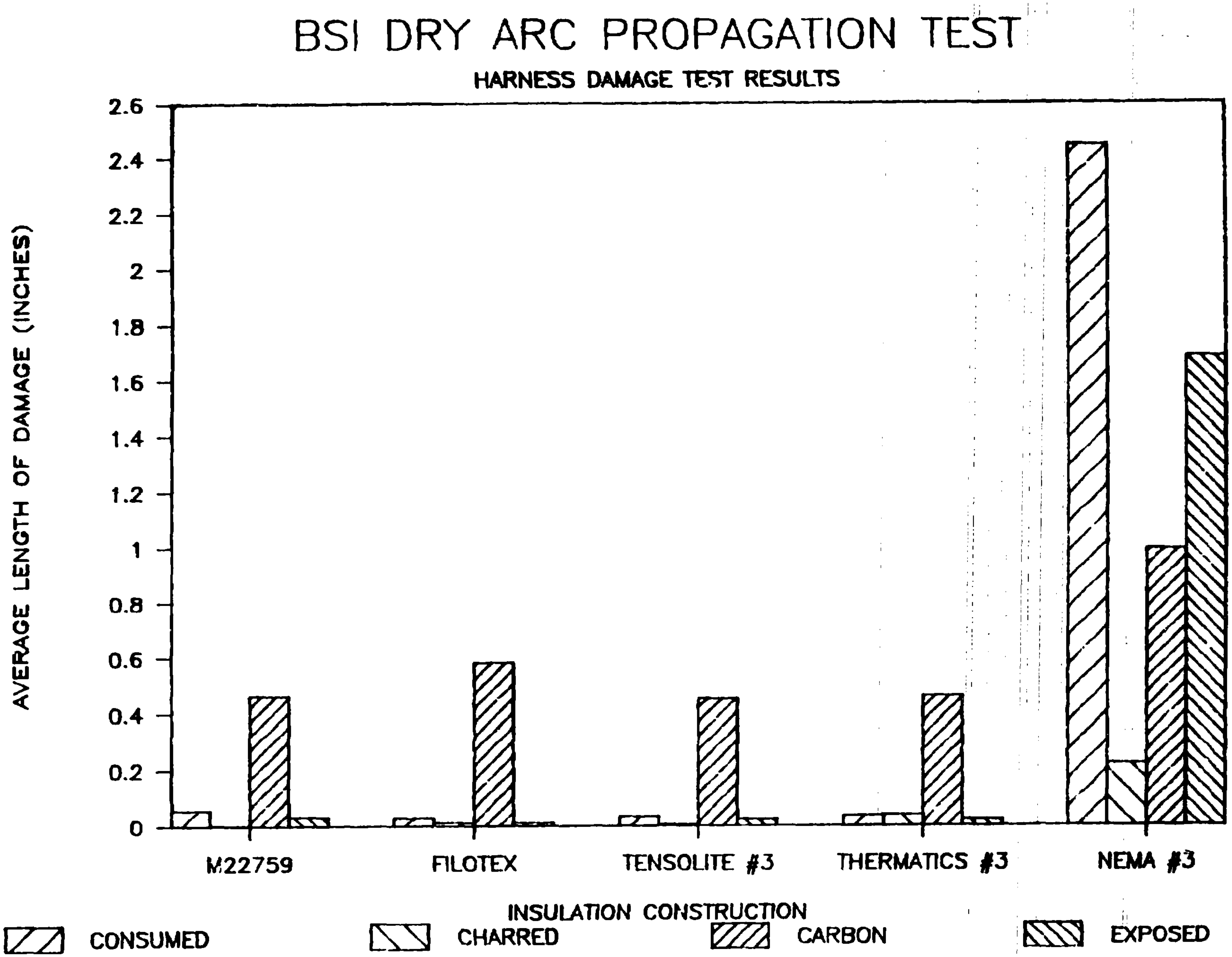


FIGURE 5.5 - BSI DRY ARC PROPAGATION TEST, HARNESS DAMAGE TEST RESULTS

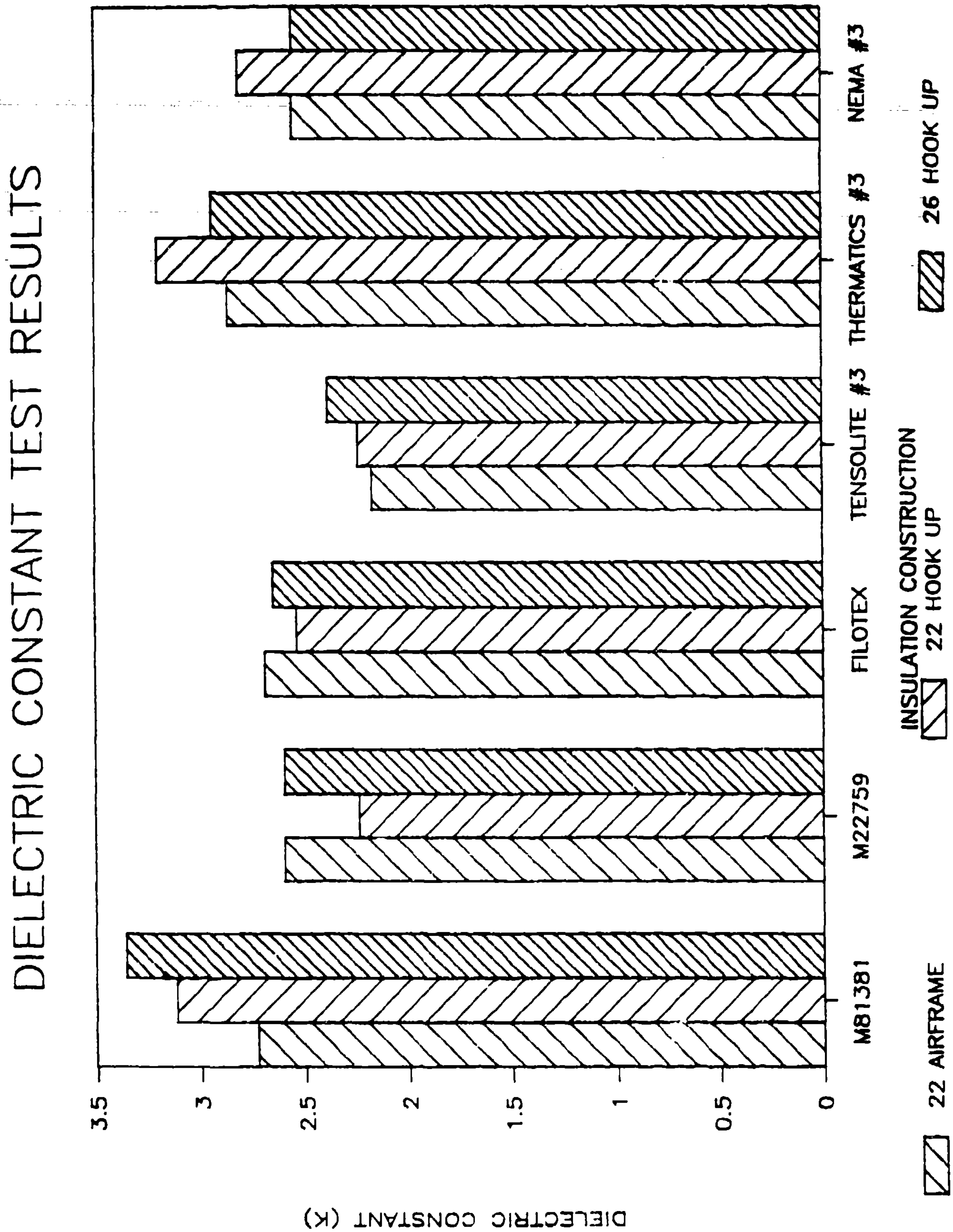


FIGURE 5.10 - DIELECTRIC CONSTANT TEST RESULTS

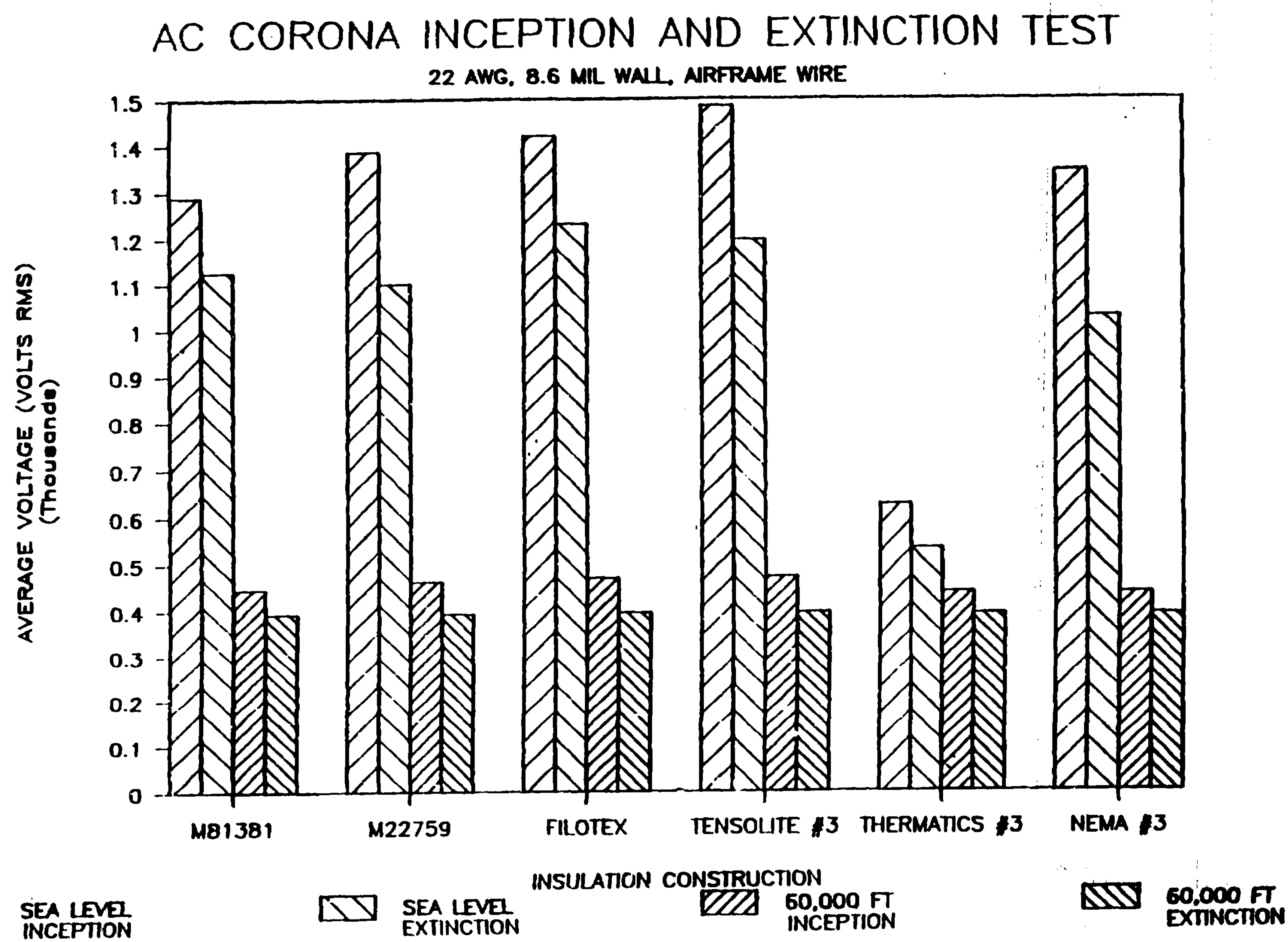


FIGURE 5.11 - AC CORONA INCEPTION AND EXTINCTION TEST,
22AWG, 8.6 MIL WALL, AIRFRAME WIRE

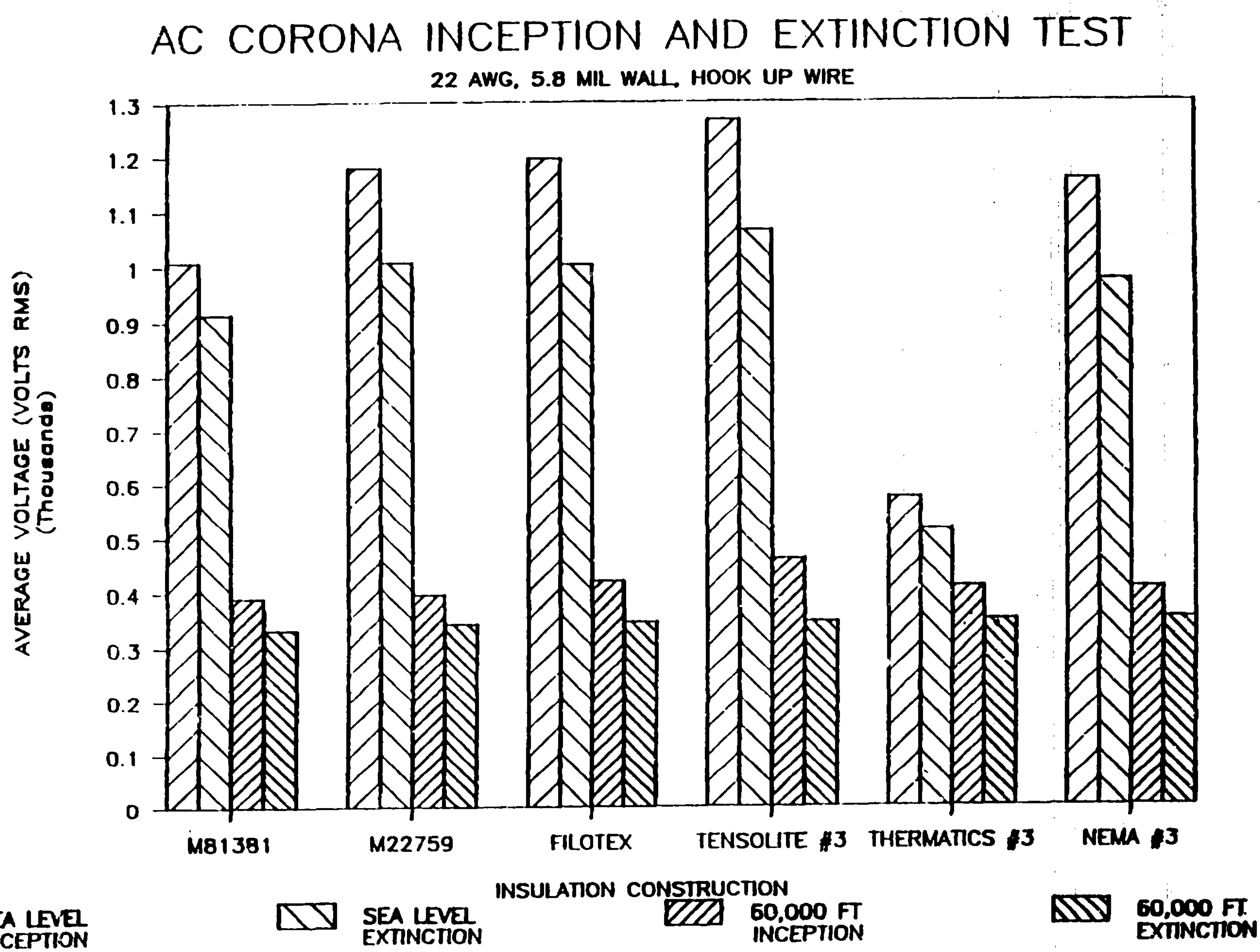


FIGURE 5.12 - AC CORONA INCEPTION AND EXTINCTION TEST, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

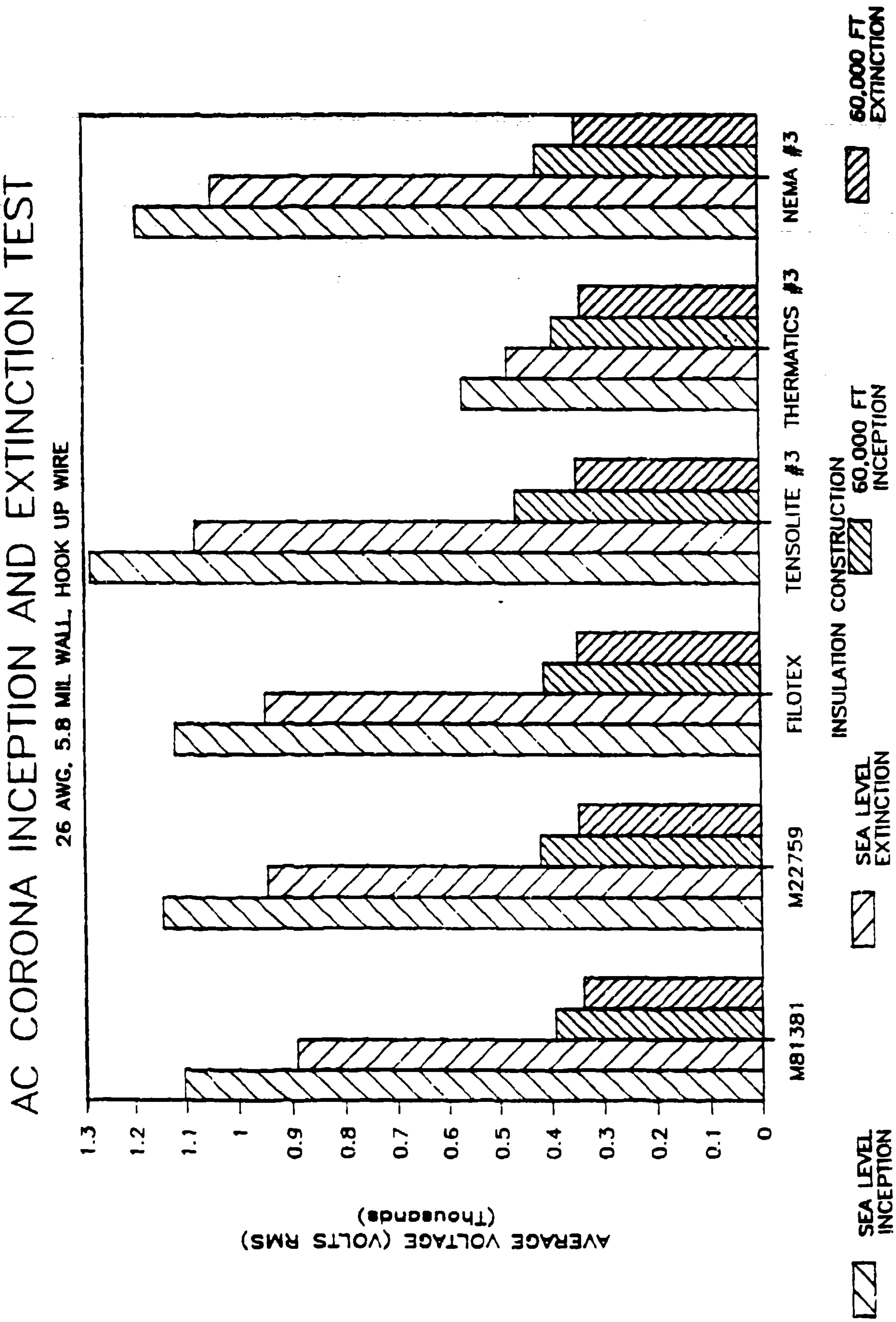


FIGURE 5.13 - AC CORONA INCEPTION AND EXTINCTION TEST, 26 AWG, 5.8 MIL WALL, HOOK UP WIRE

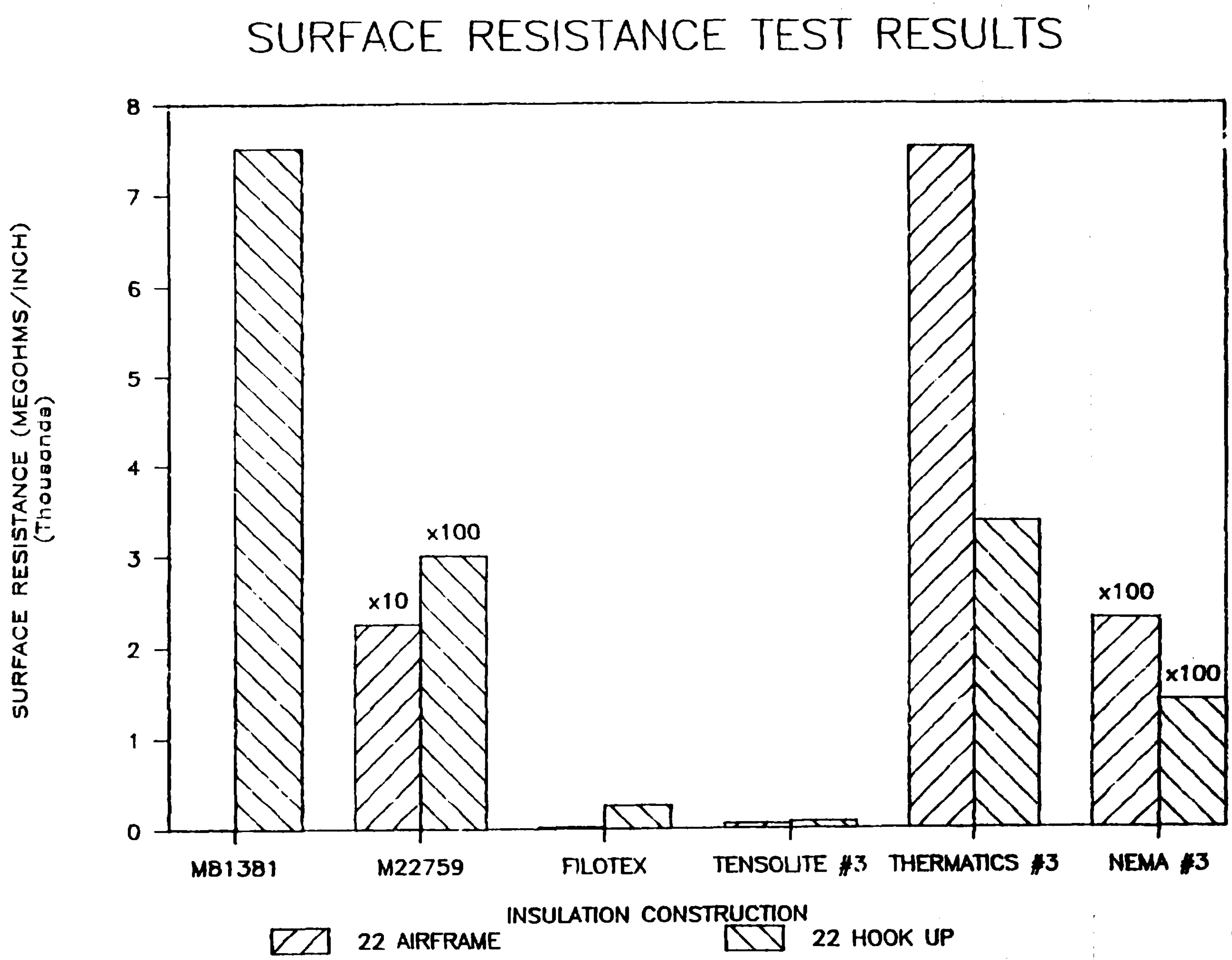


FIGURE 5.1? - SURFACE RESISTANCE TEST RESULTS

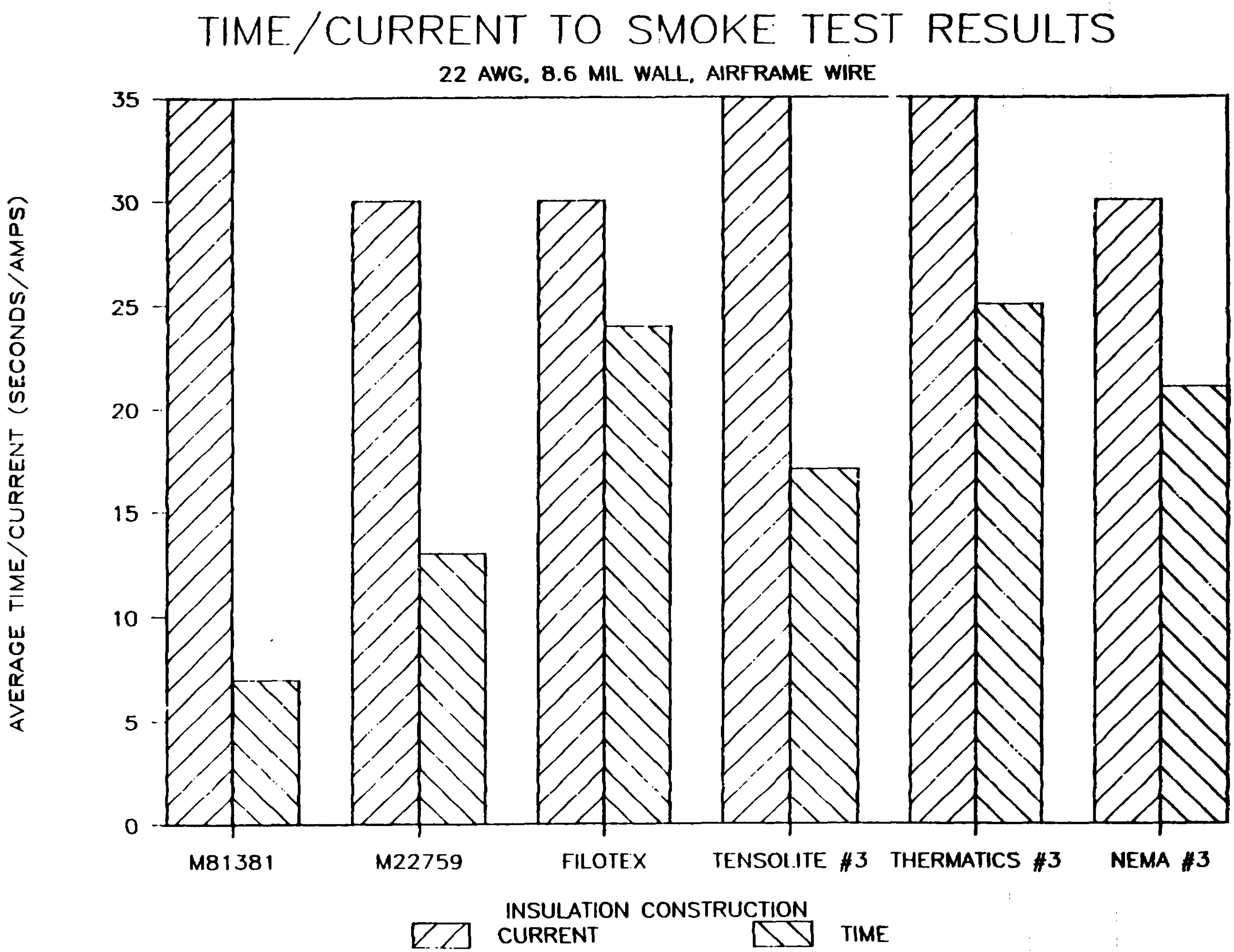


FIGURE 5.18 - TIME/CURRENT TO SMOKE TEST RESULTS, 22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

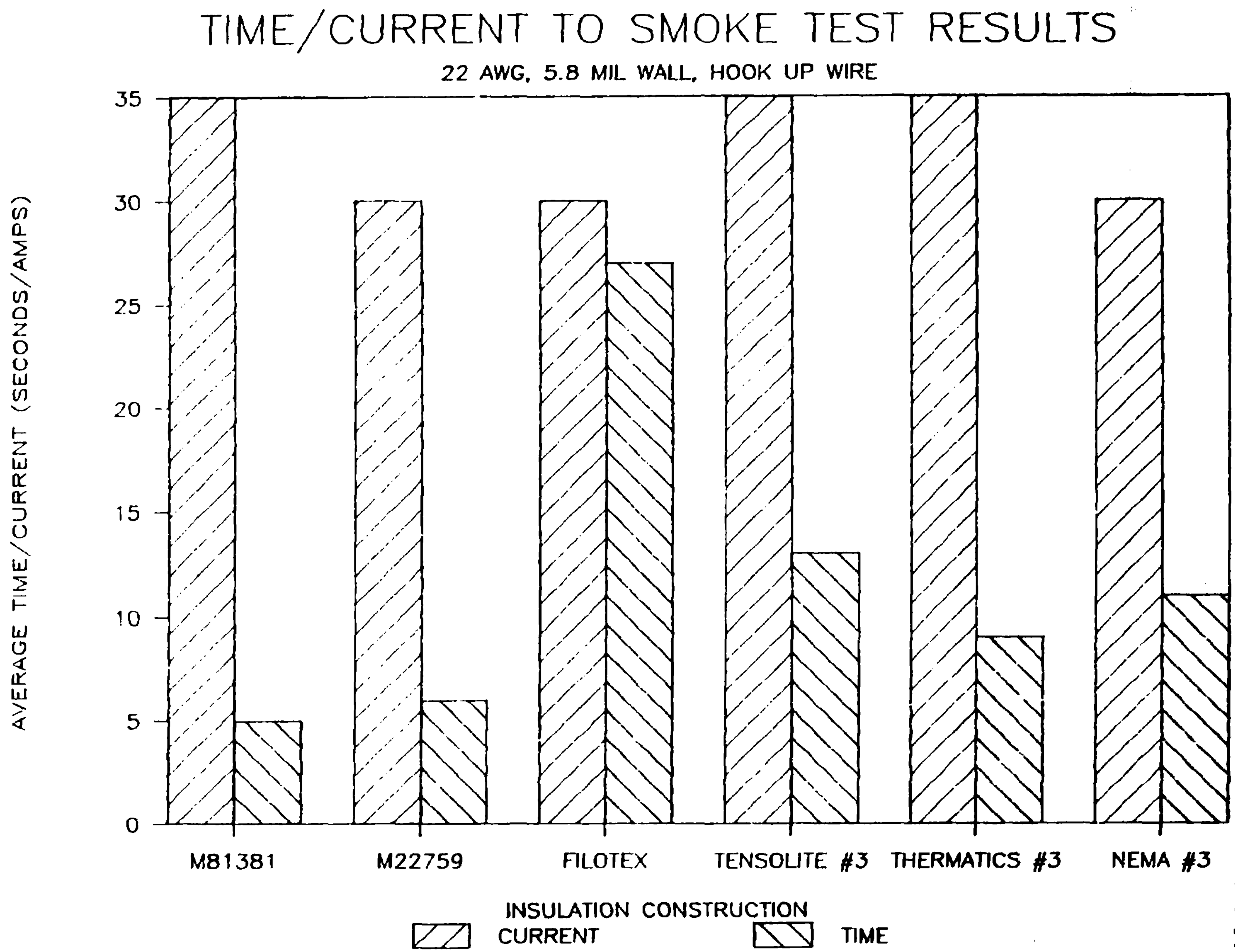


FIGURE 5.19 - TIME/CURRENT TO SMOKE TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

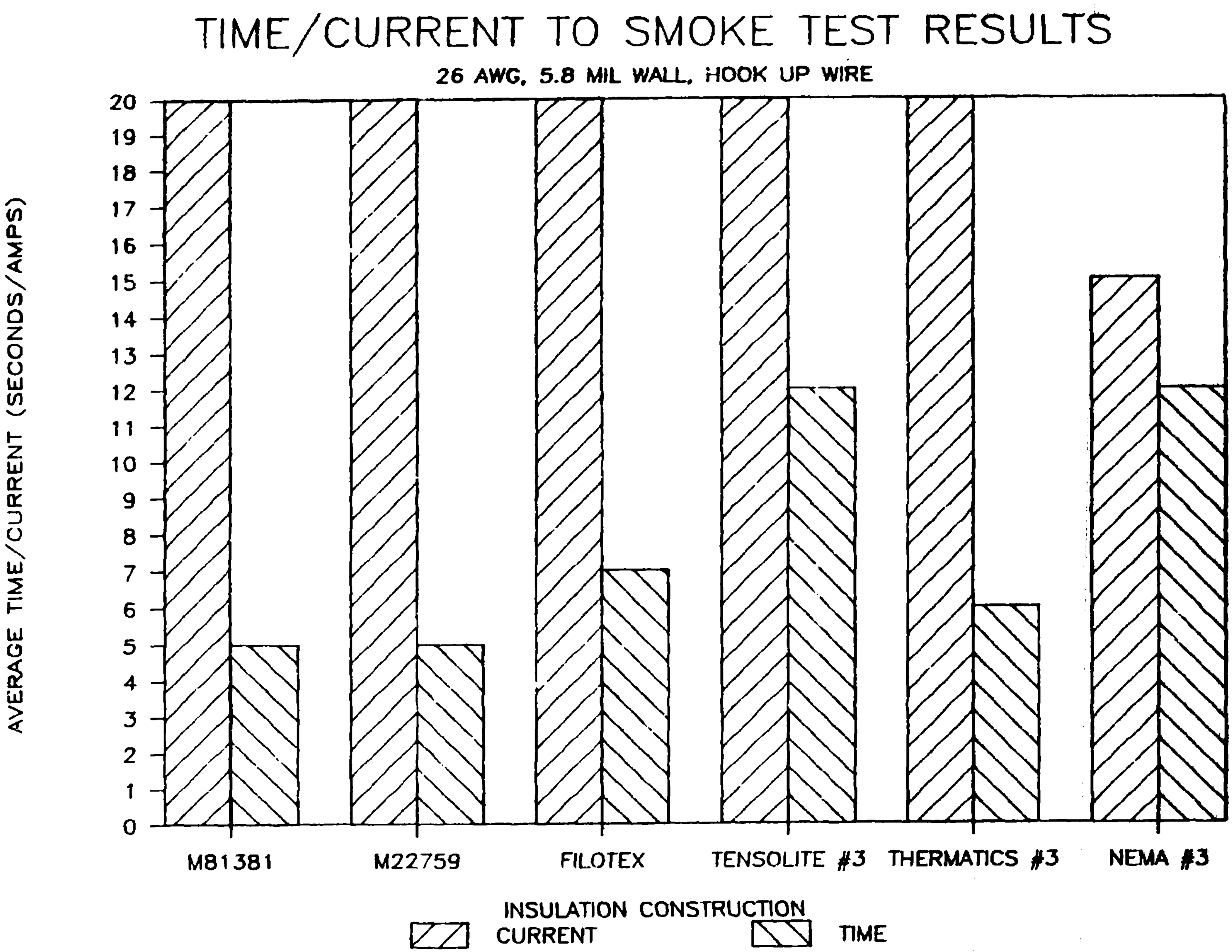
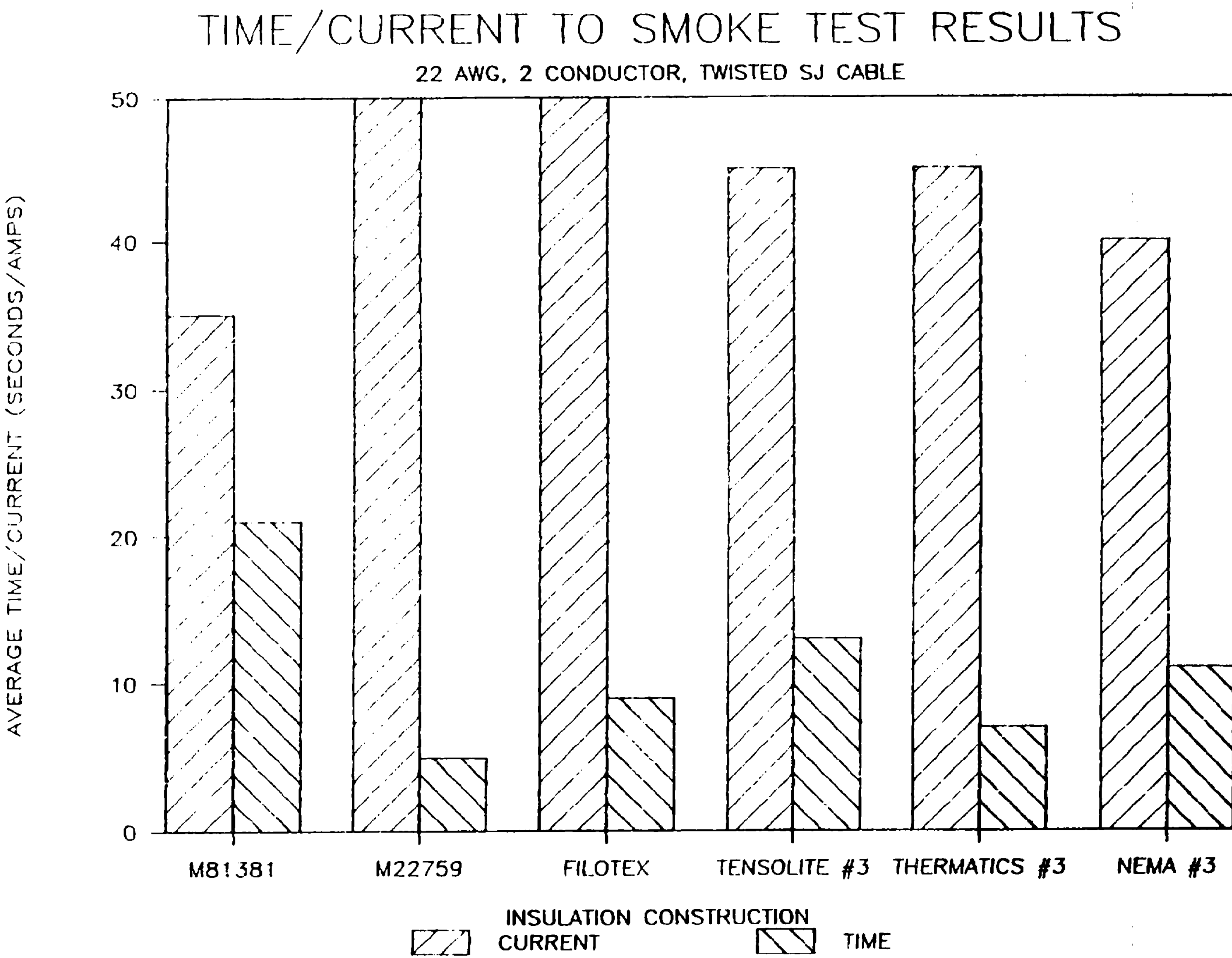


FIGURE 5.20 - TIME/CURRENT TO SMOKE TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE



<u>FIGURE 5.21 - TIME/CURRENT TO SMOKE TEST RESULTS,</u>
<u>22AWG, 2 CONDUCTOR, TWISTED SJ CABLE</u>

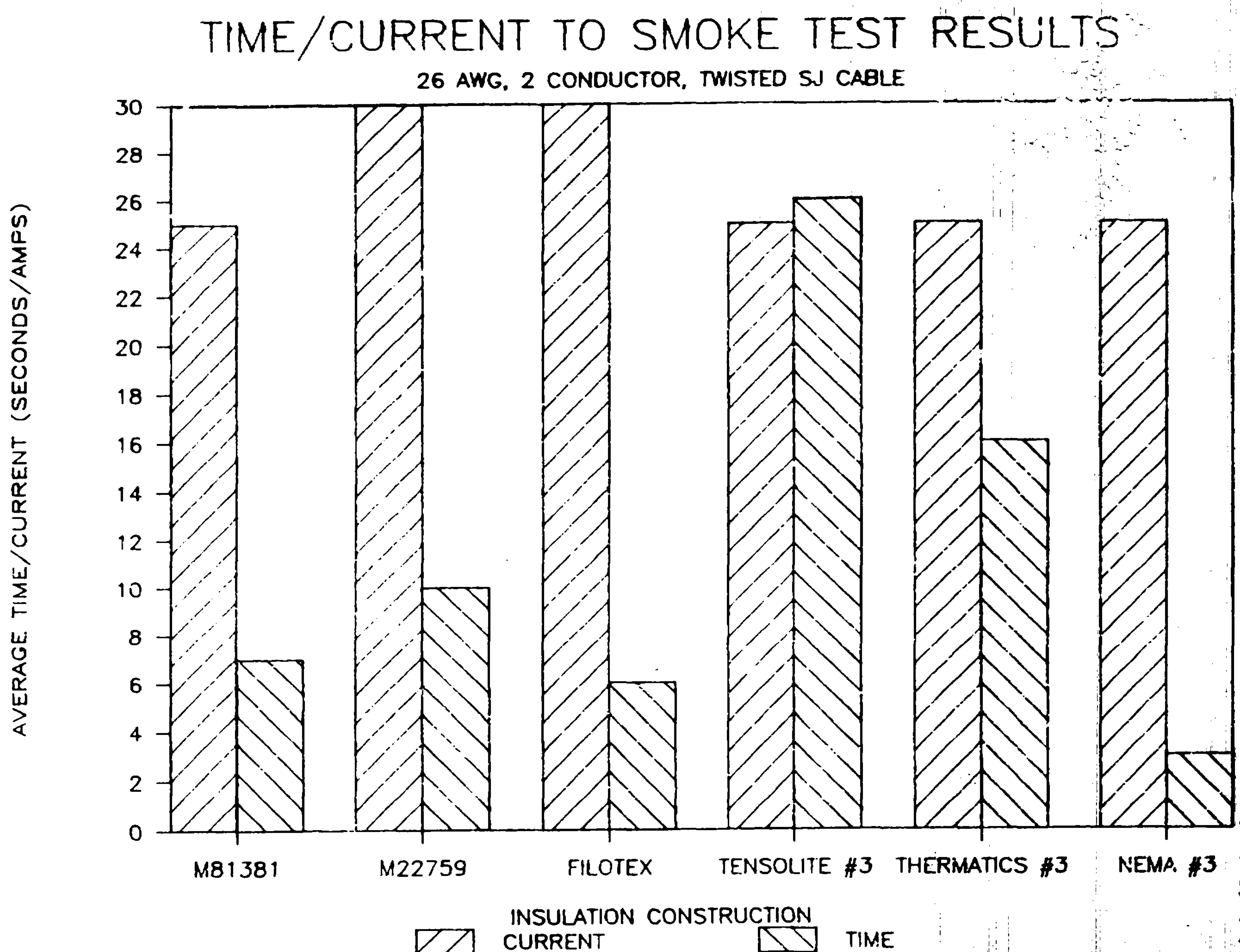


FIGURE 5.22 - TIME/CURRENT TO SMOKE TEST RESULTS, 26AWG, 2 CONDUCTOR, TWISTED SJ CABLE

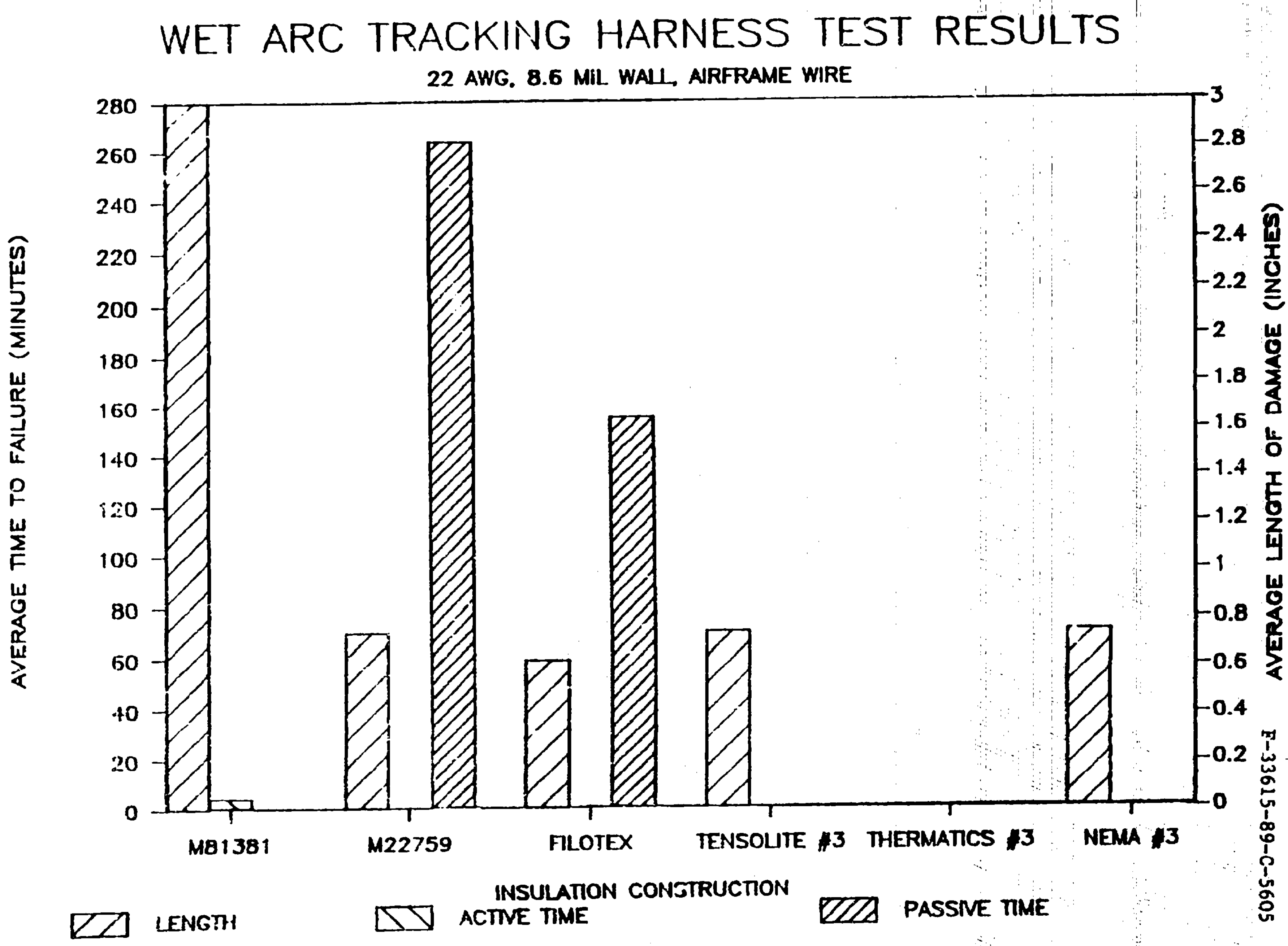


FIGURE 5.23 - WET ARC TRACKING HARNESS TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

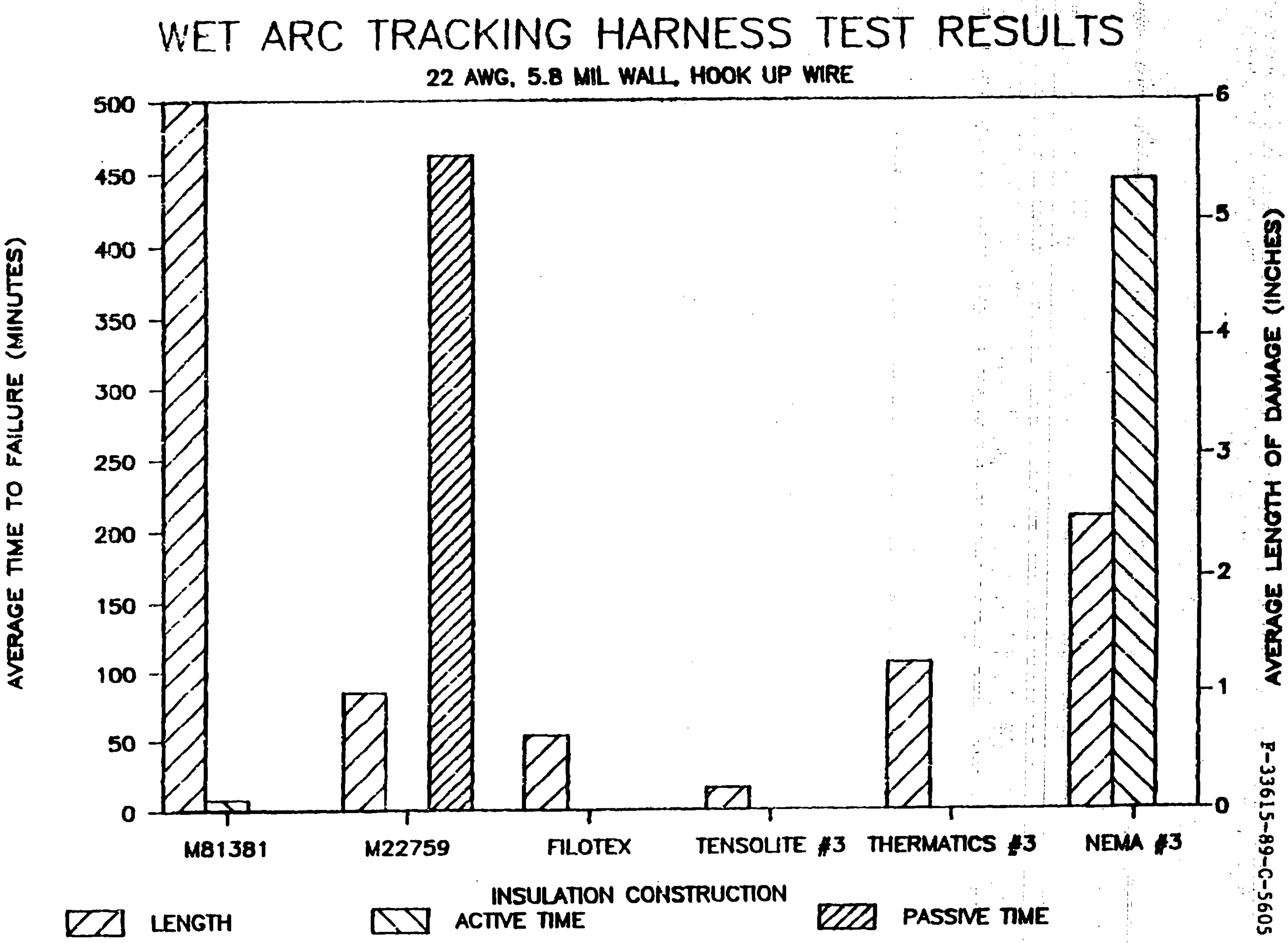


FIGURE 5.24 - WET ARC TRACKING HARNESS TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

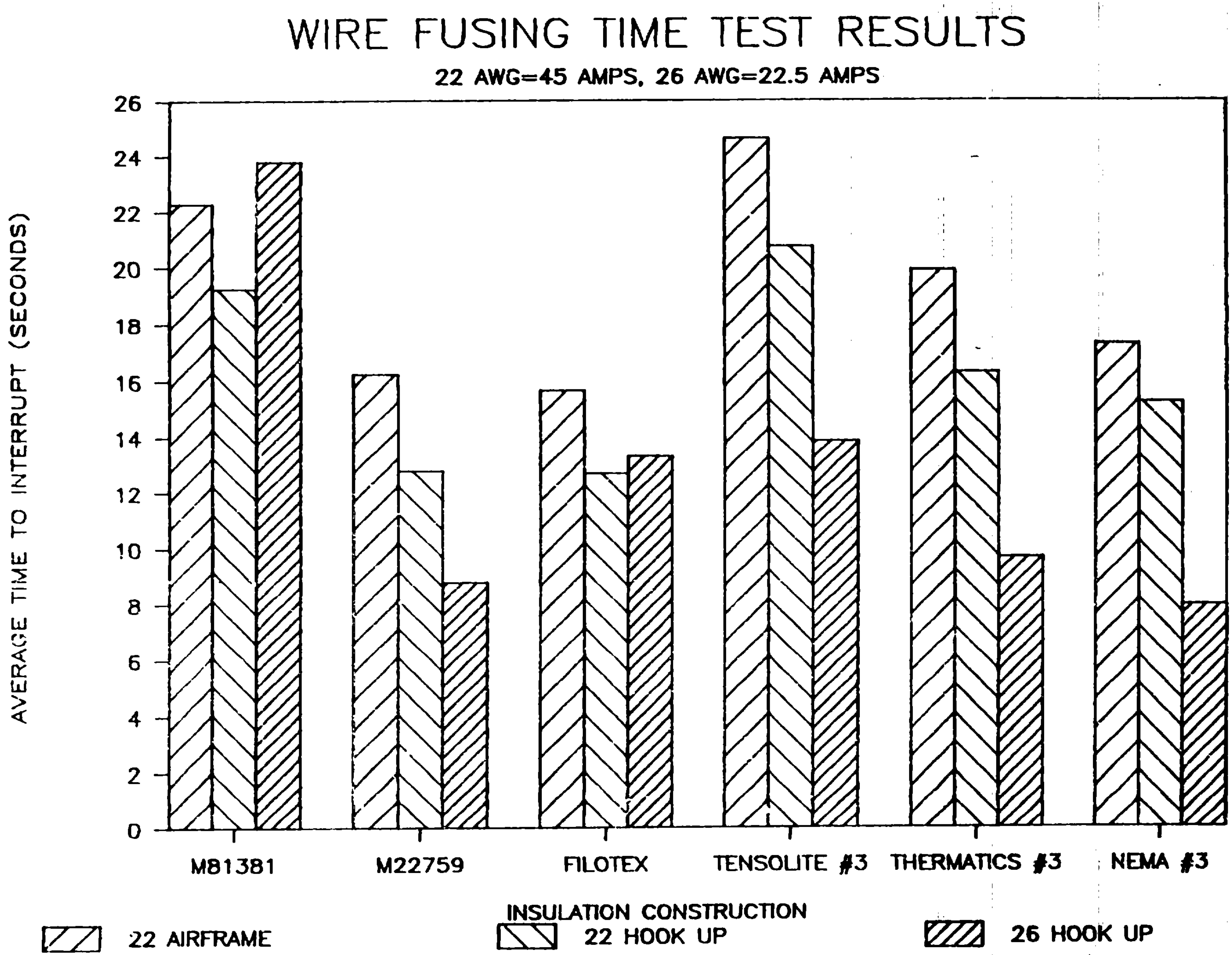


FIGURE 5.28 - WIRE FUSING TIME TEST RESULTS, 22AWG=45 AMPS, 26 AWG=22.5 AMPS

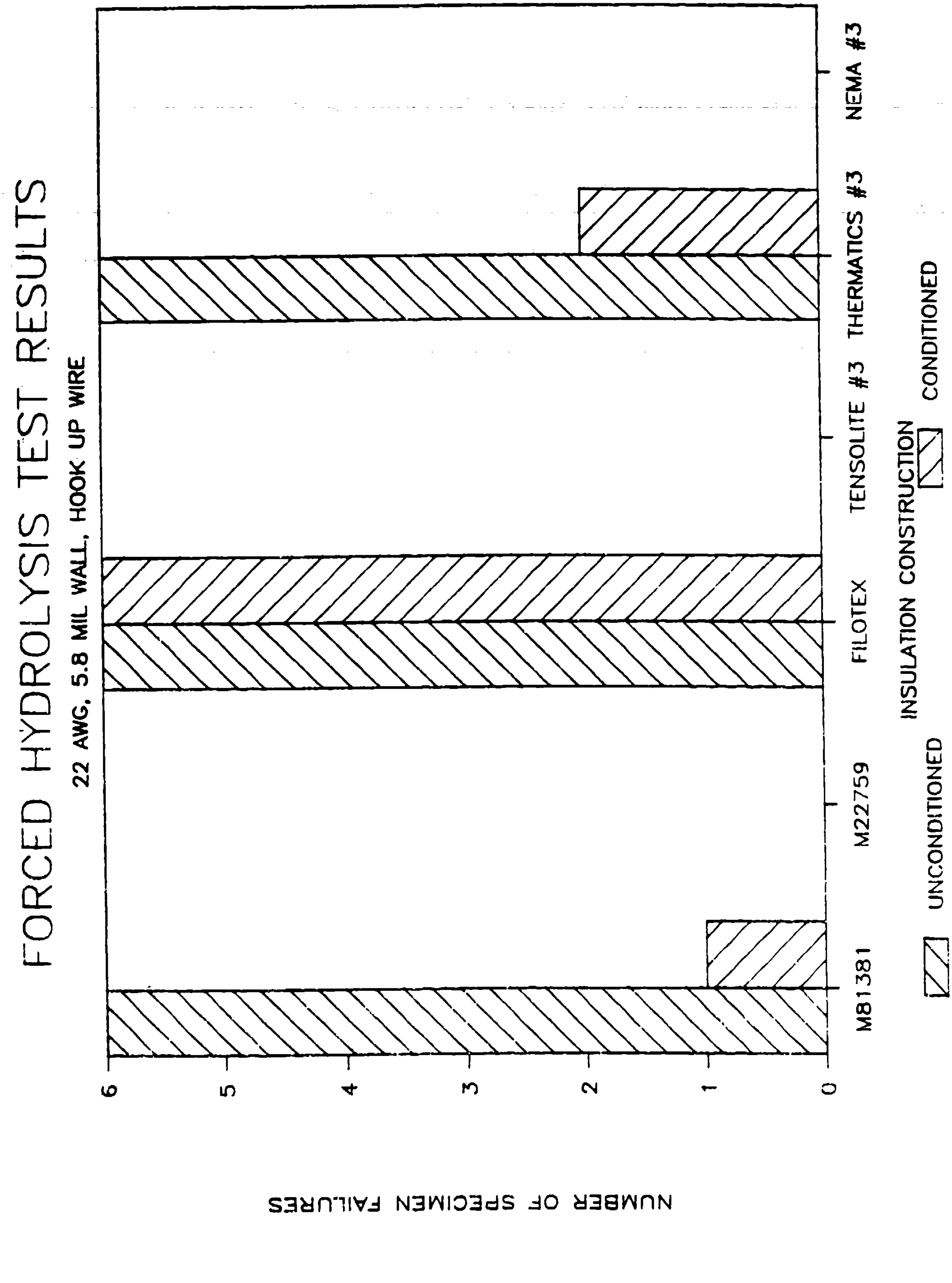


FIGURE 5.31 - FORCED HYDROLYSIS TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

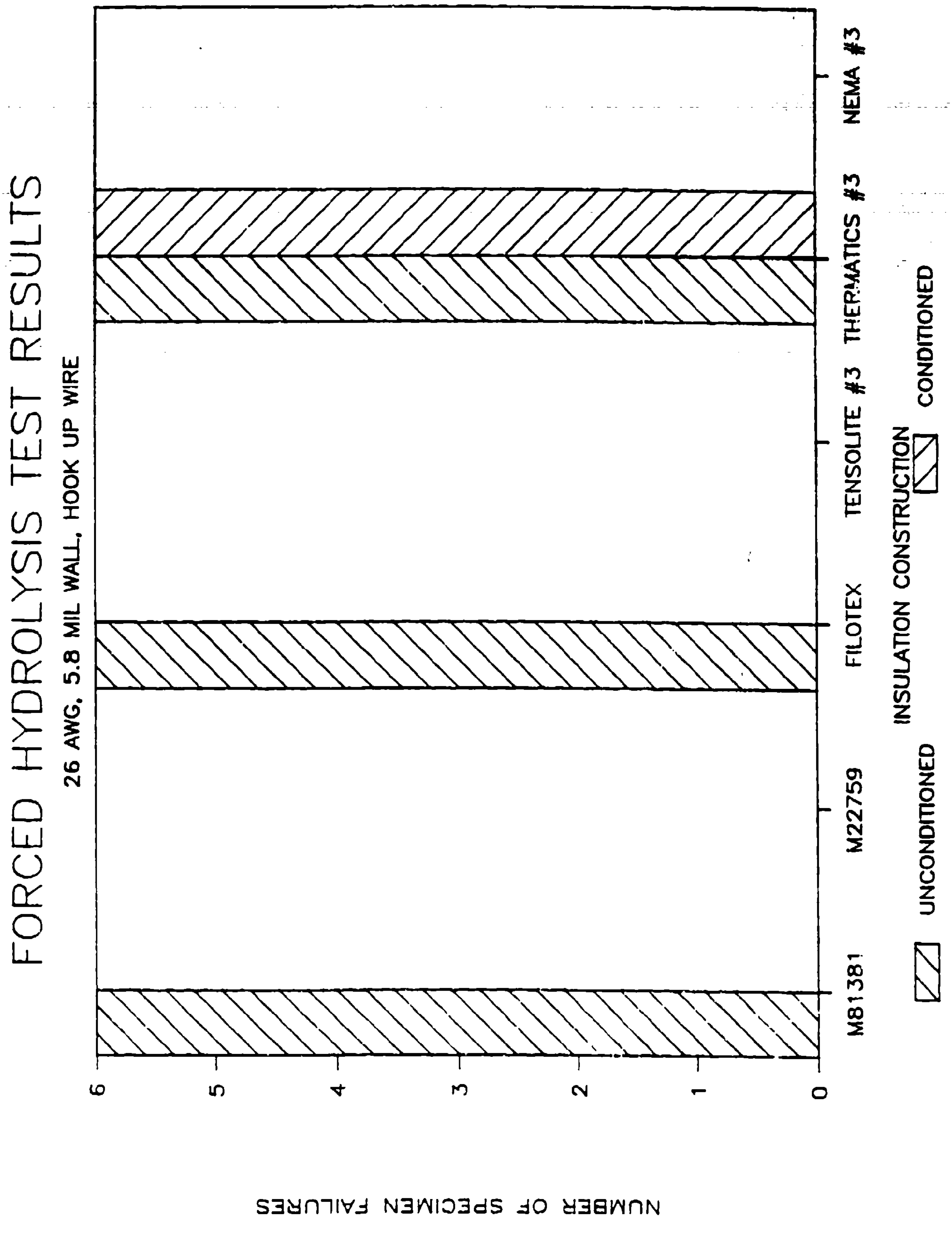


FIGURE 5.32 - FORCED HYDROLYSIS TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

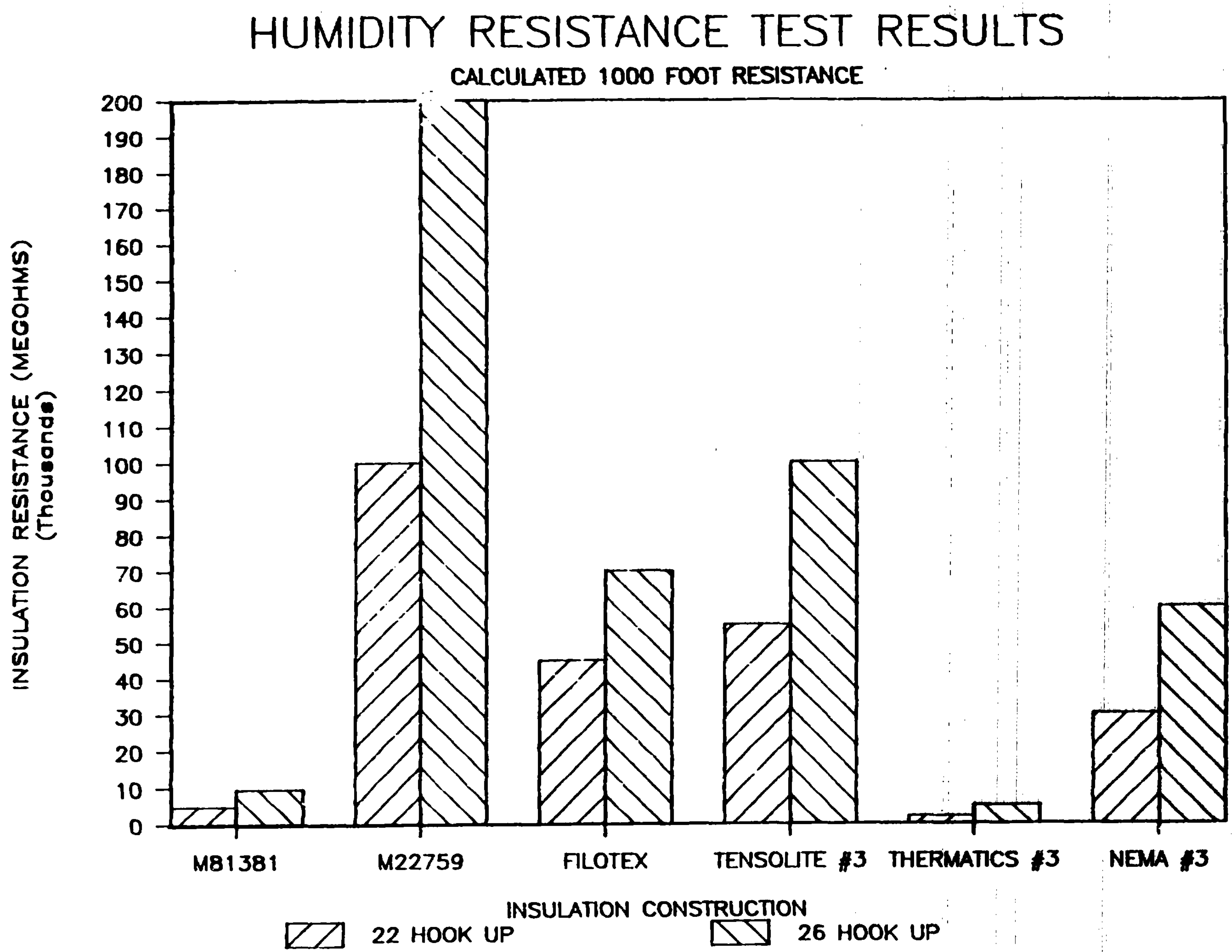


FIGURE 5.37 - HUMIDITY RESISTANCE TEST RESULTS, CALCULATED 1000 FOOT RESISTANCE

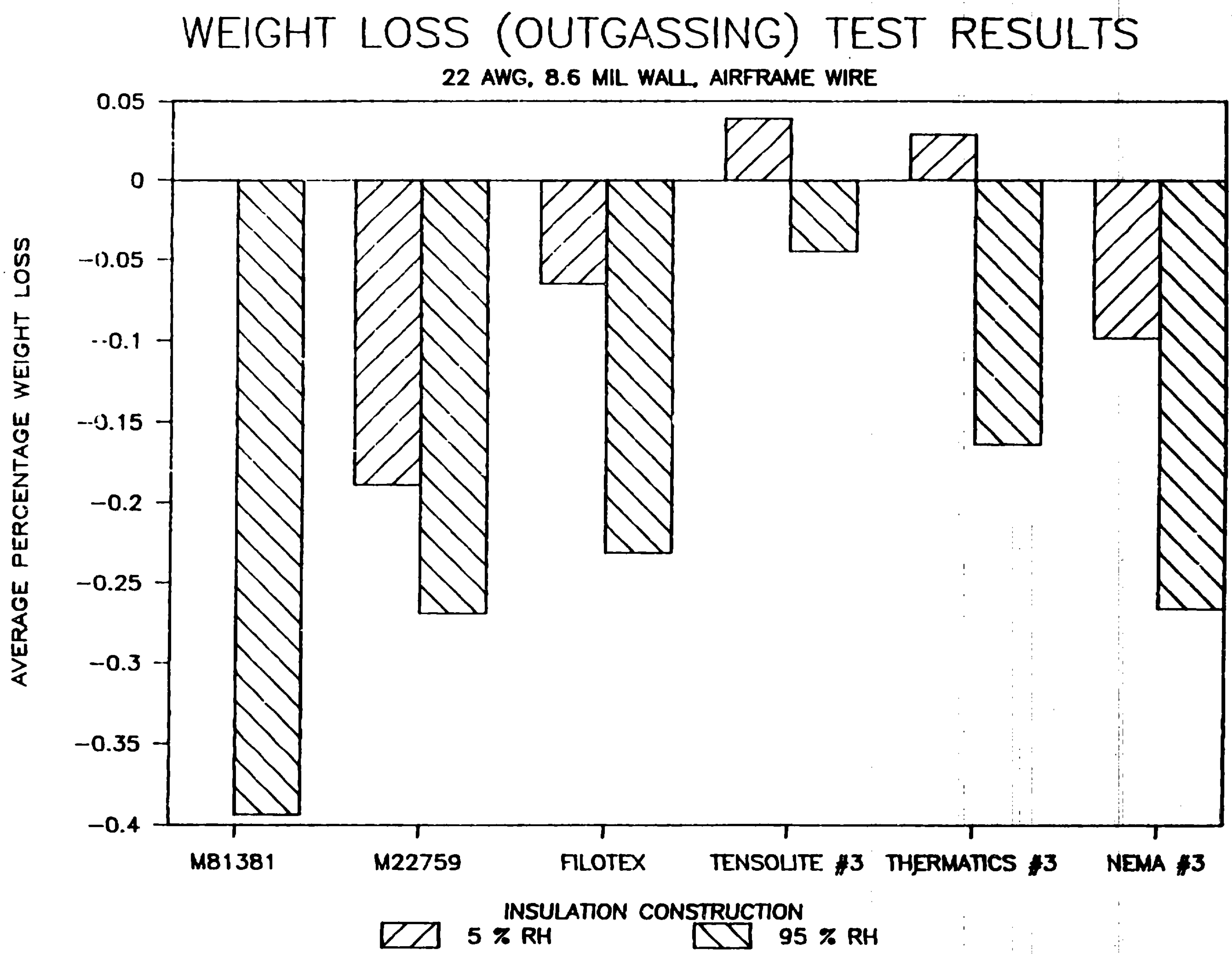


FIGURE 5.40 - WEIGHT LOSS (OUTGASSING) TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

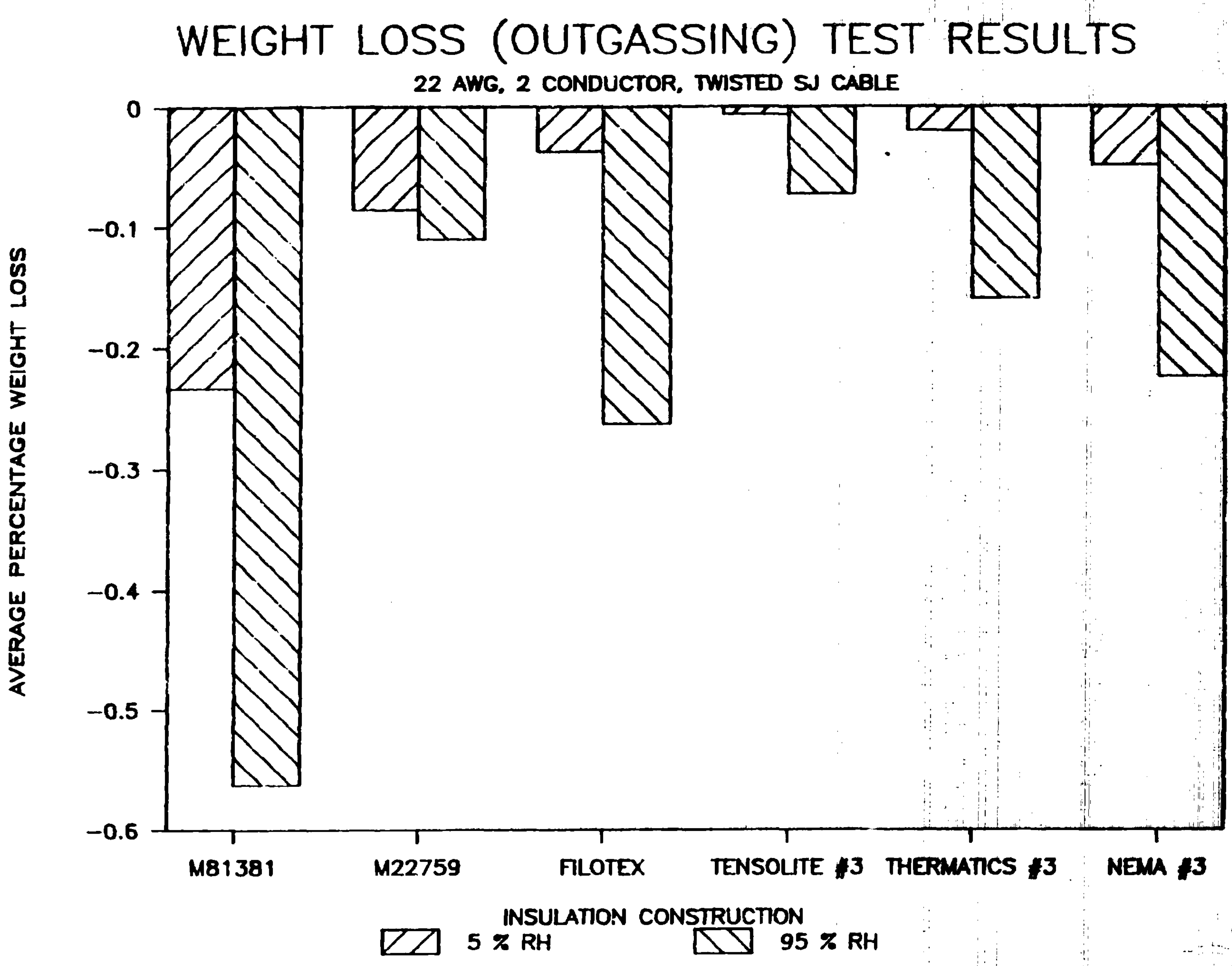


FIGURE 5.41 - WEIGHT LOSS (OUTGASSING) TEST RESULTS, 22AWG, 2 CONDUCTOR, TWISTED SJ CABLE

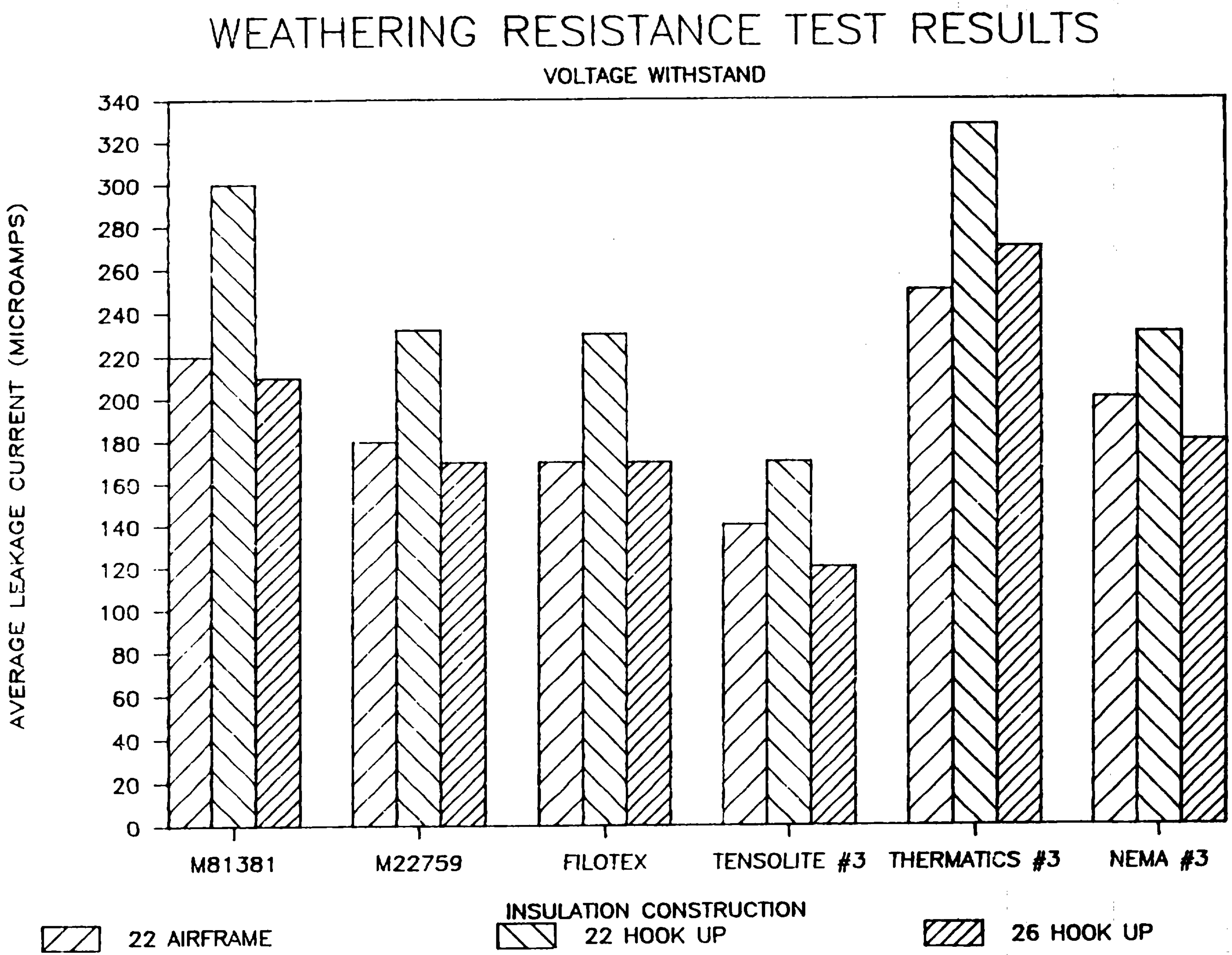


FIGURE 5.45 - WEATHERING RESISTANCE TEST RESULTS, VOLTAGE WITHSTAND

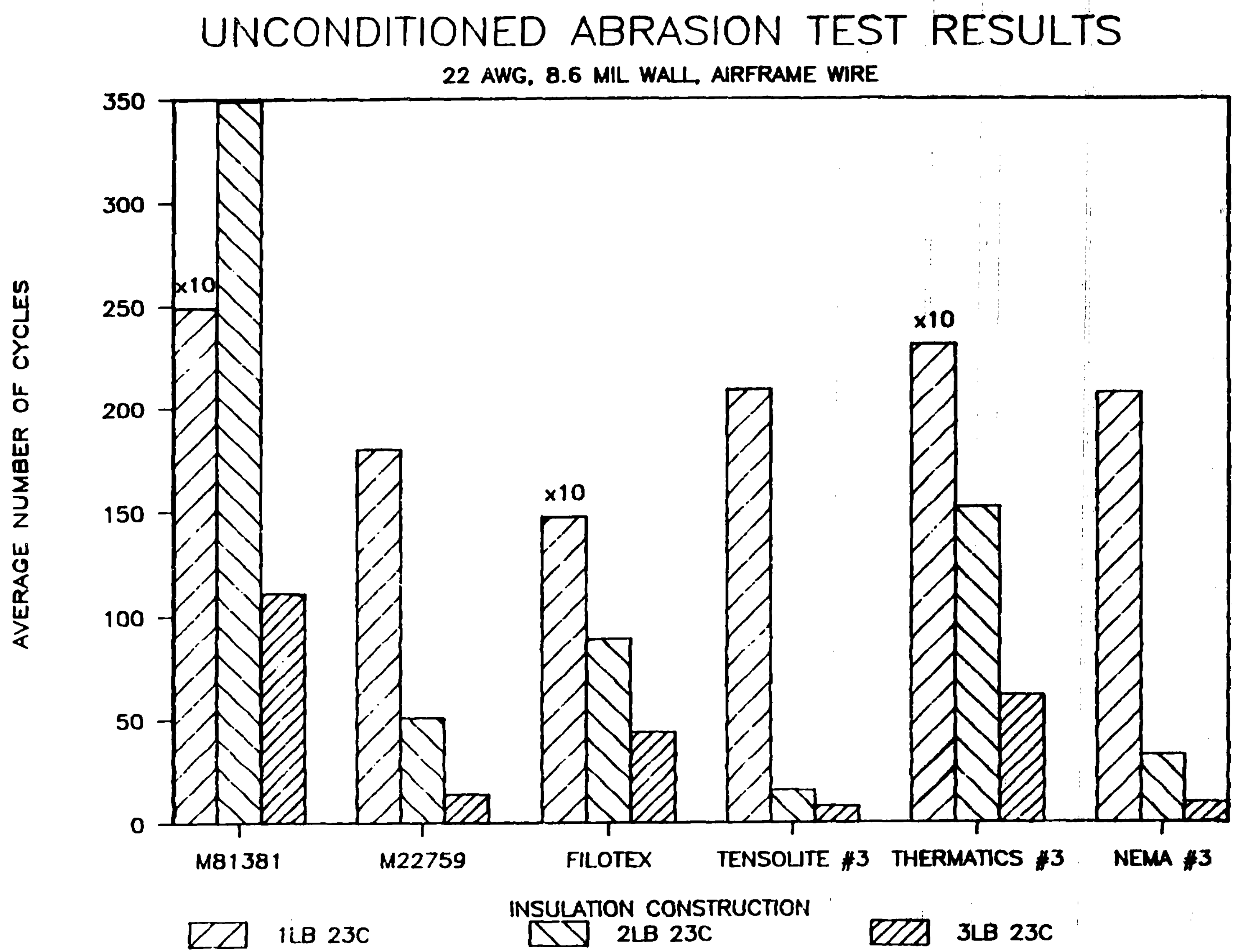


FIGURE 5.49 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 23°C

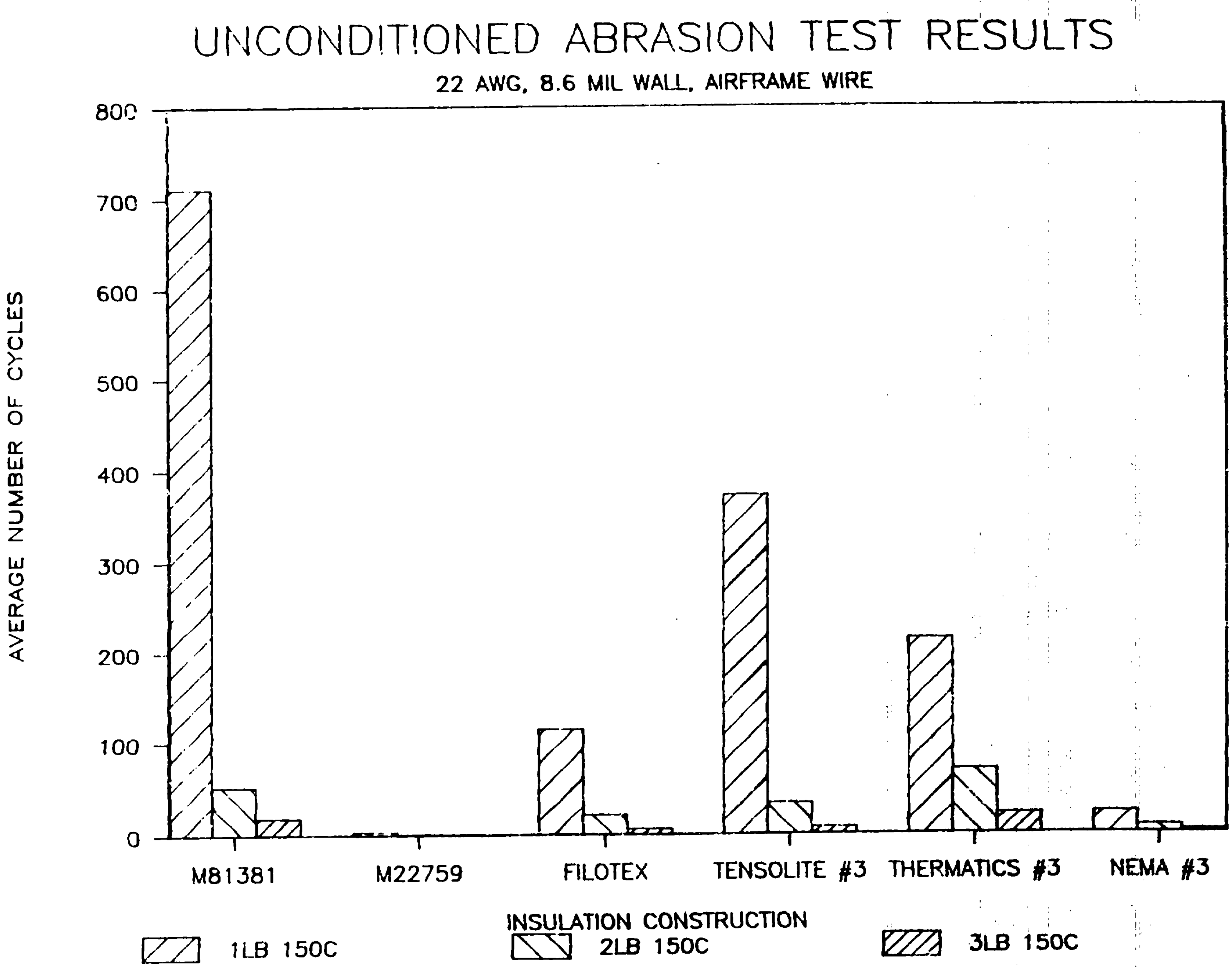


FIGURE 5.50 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 150°C

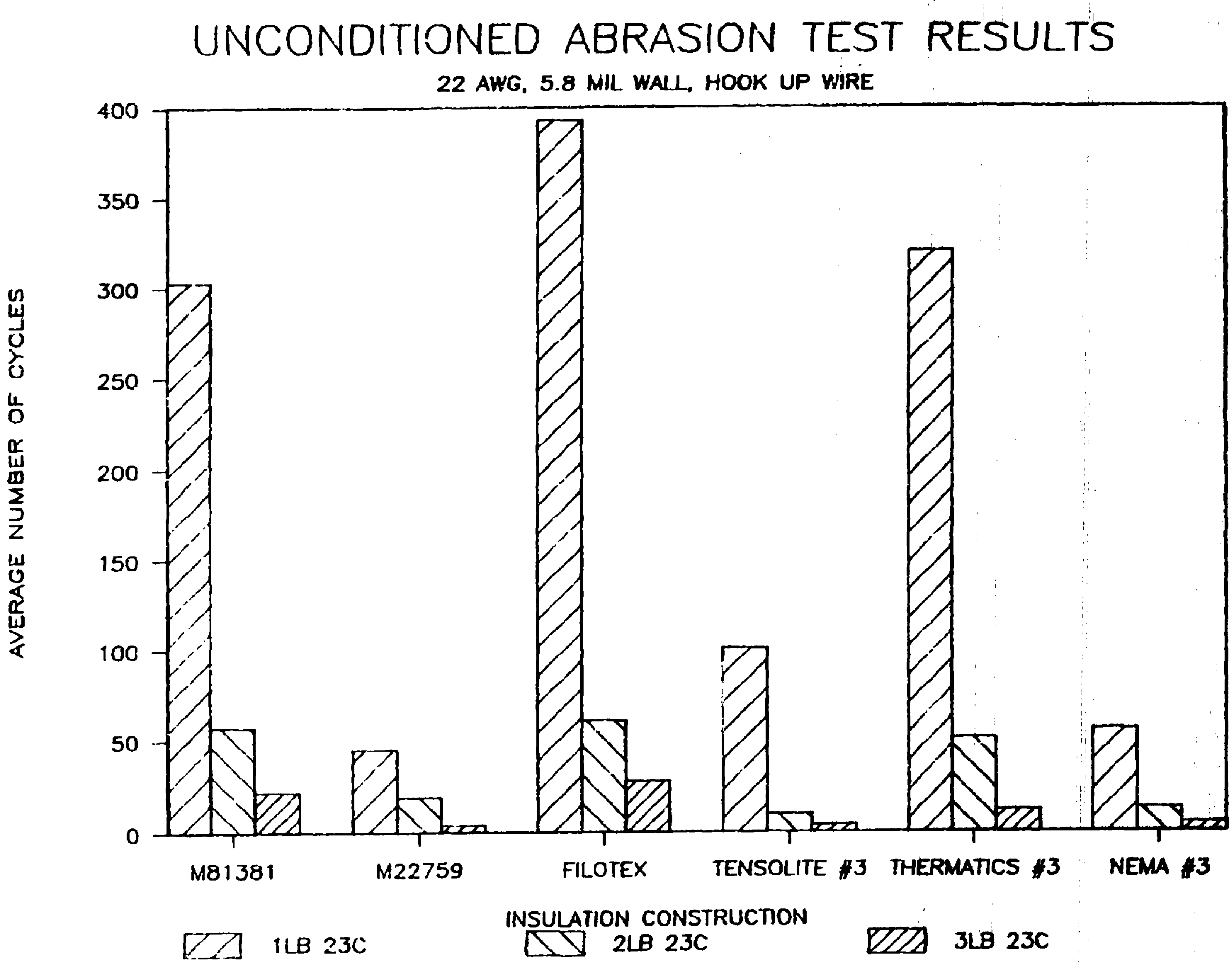


FIGURE 5.51 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 23°C

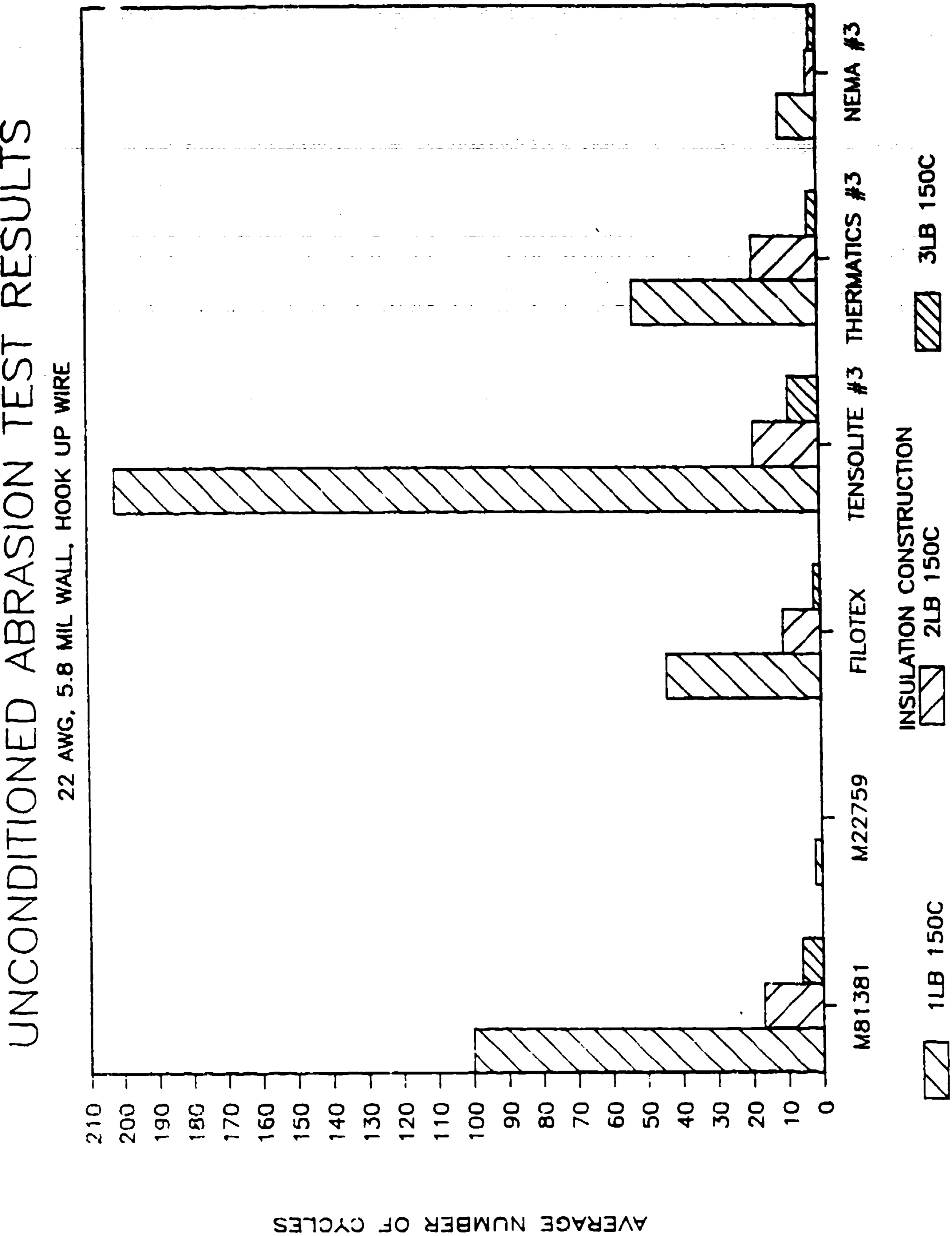


FIGURE 5.52 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 150°C

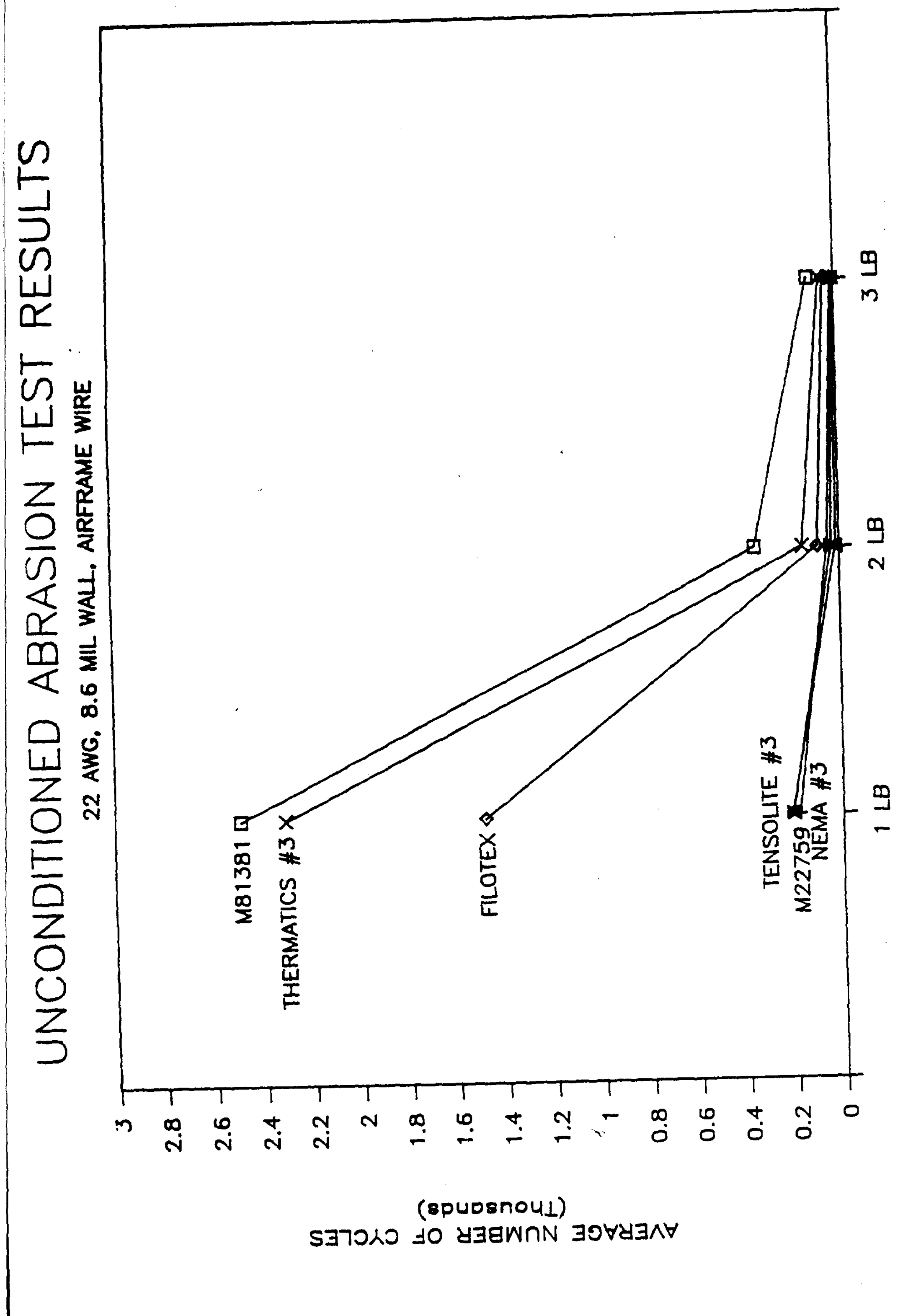


FIGURE 5.53 UNCONDITIONED ABRASION TEST RESULTS,
22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 23°C

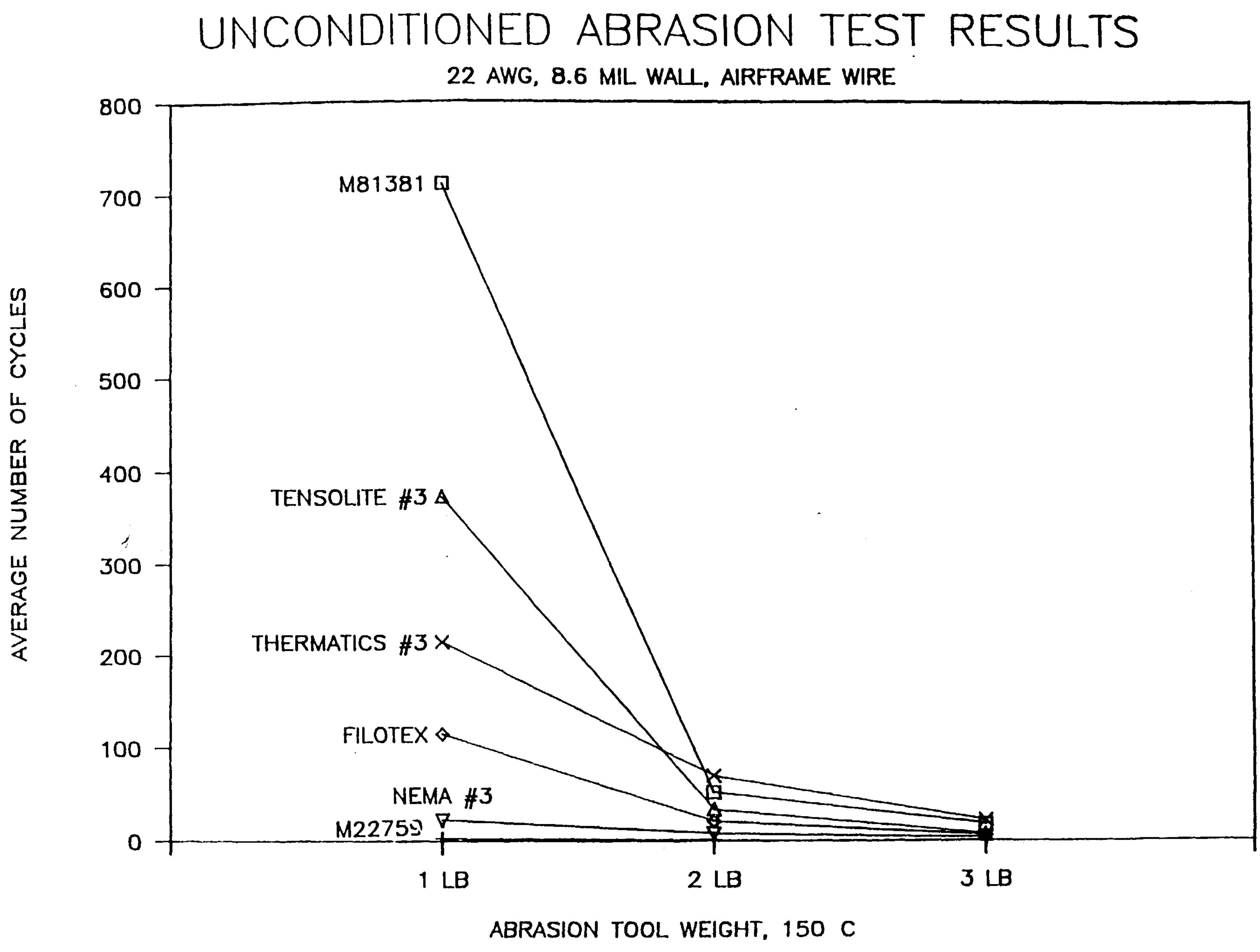


FIGURE 5.54 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE AT 150°C

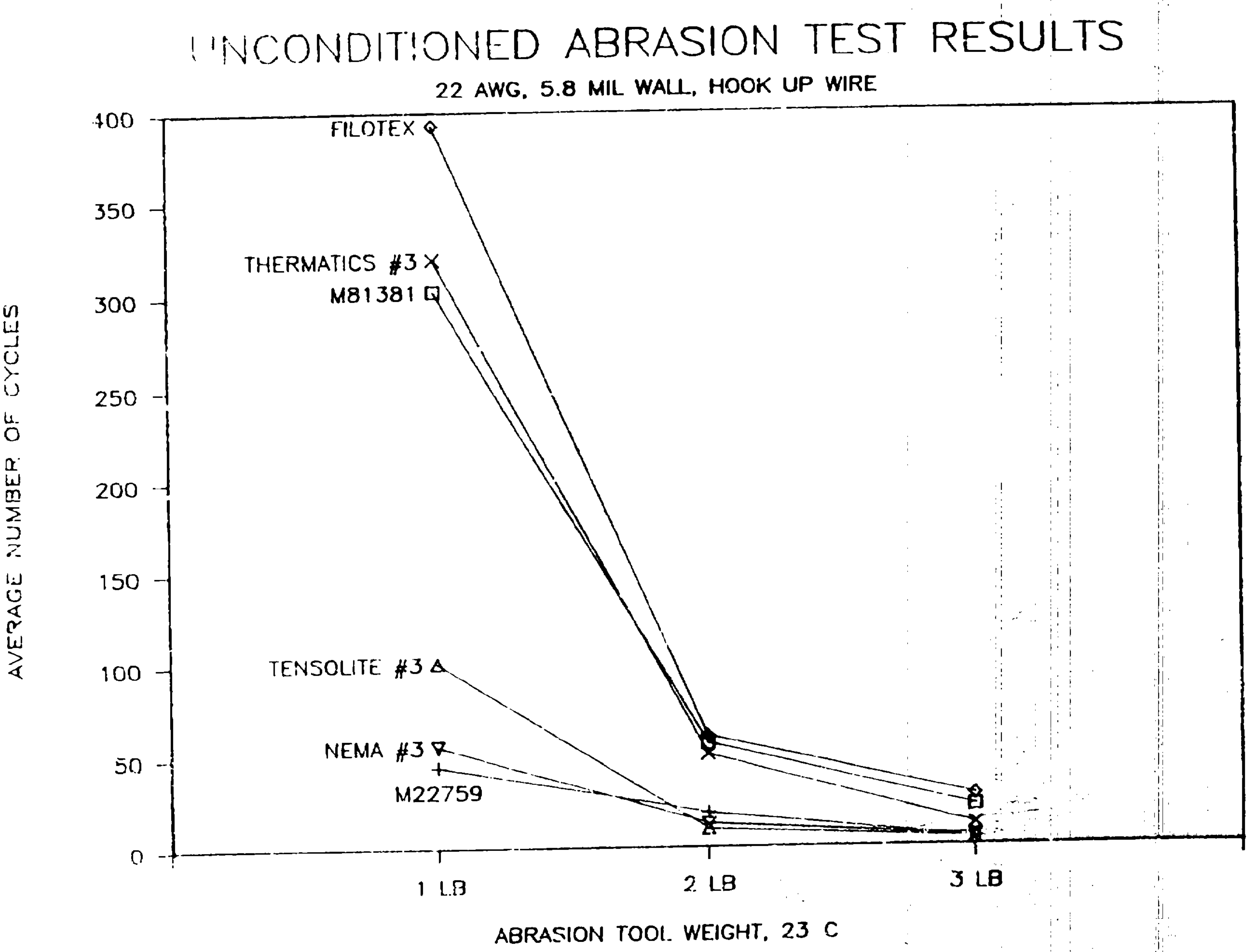


FIGURE 5.55 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 23°C

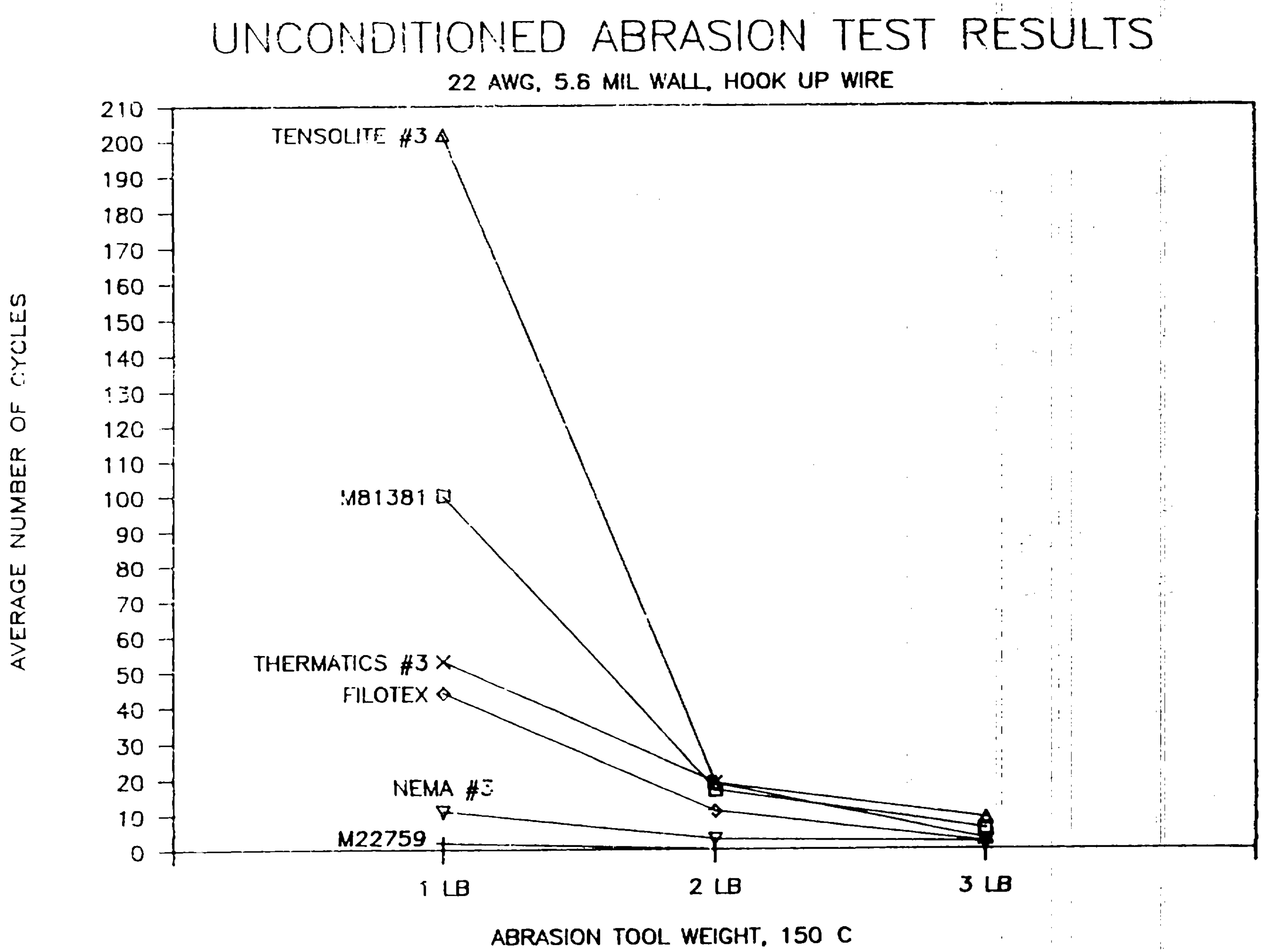


FIGURE 5.56 - UNCONDITIONED ABRASION TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 150°C

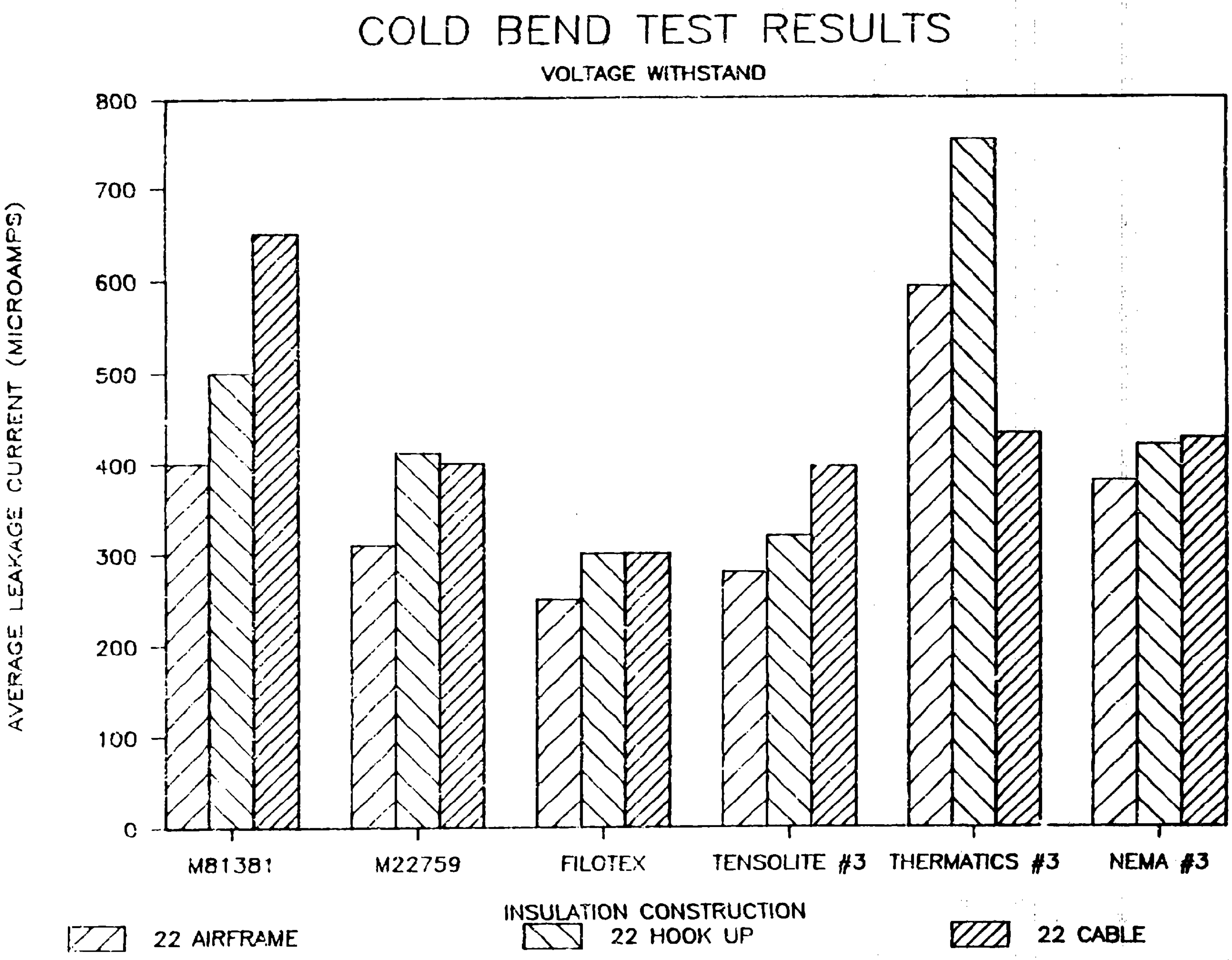


FIGURE 5.57 - COLD BEND TEST RESULTS

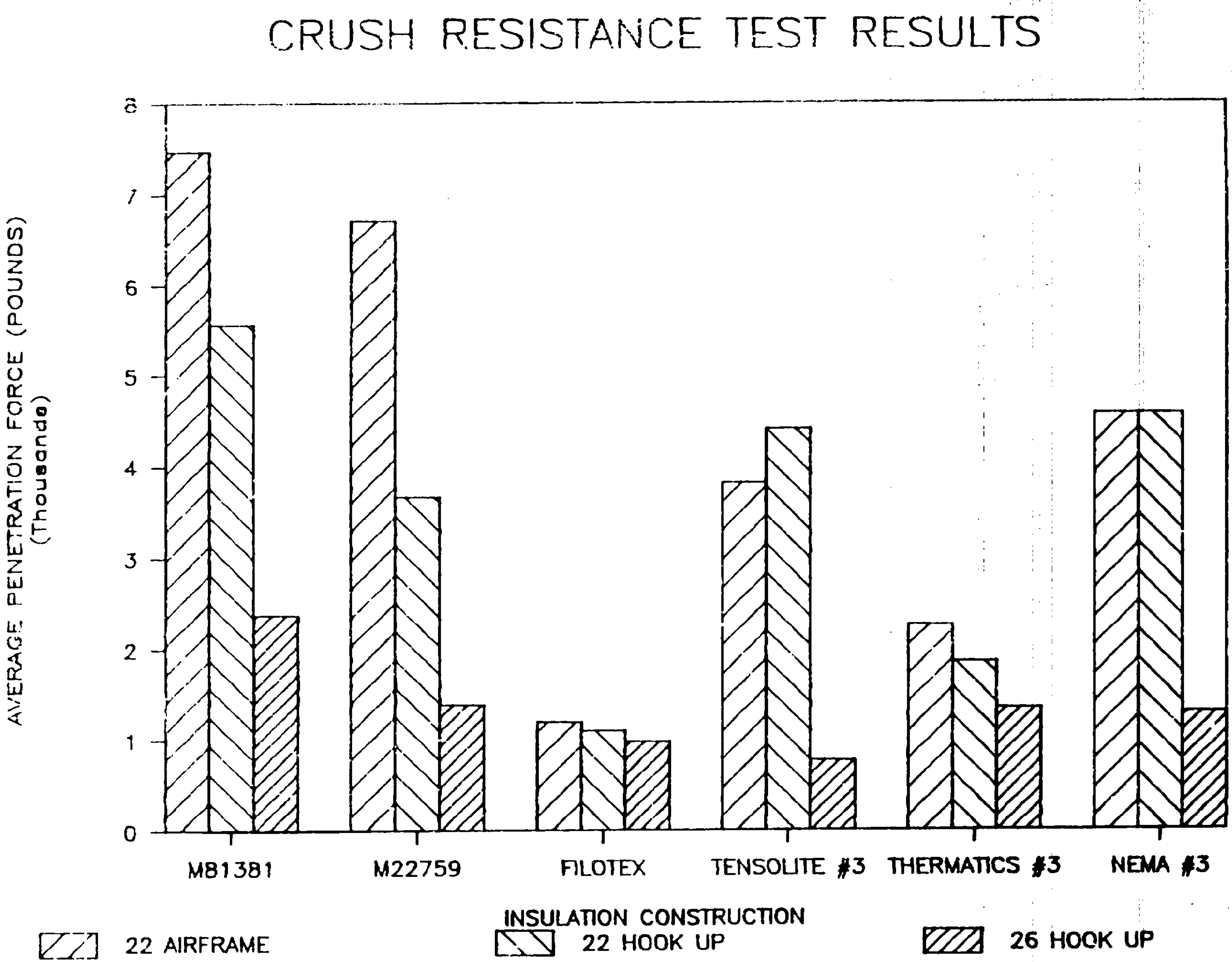


FIGURE 5.61 - CRUSH RESISTANCE TEST RESULTS

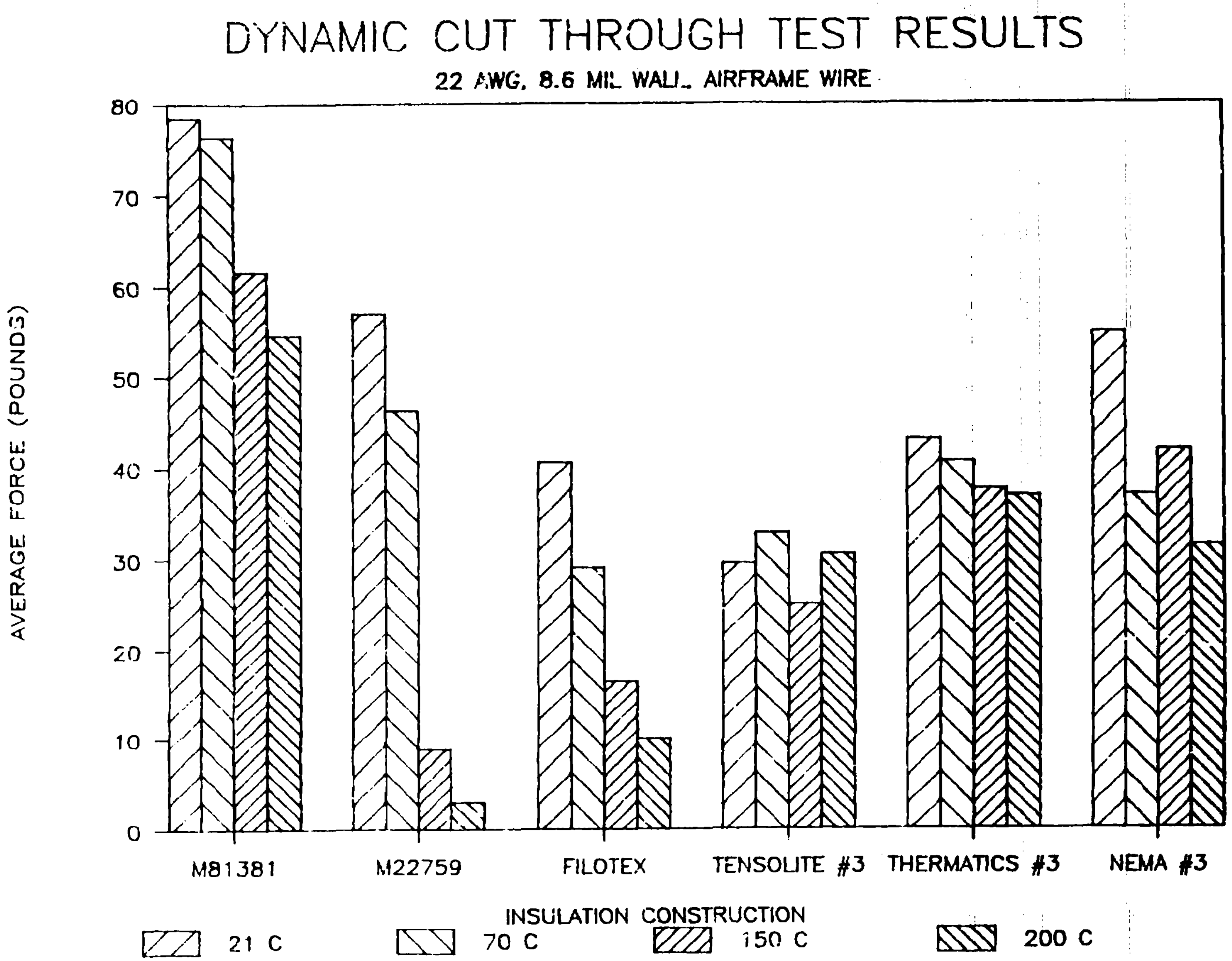


FIGURE 5.64 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

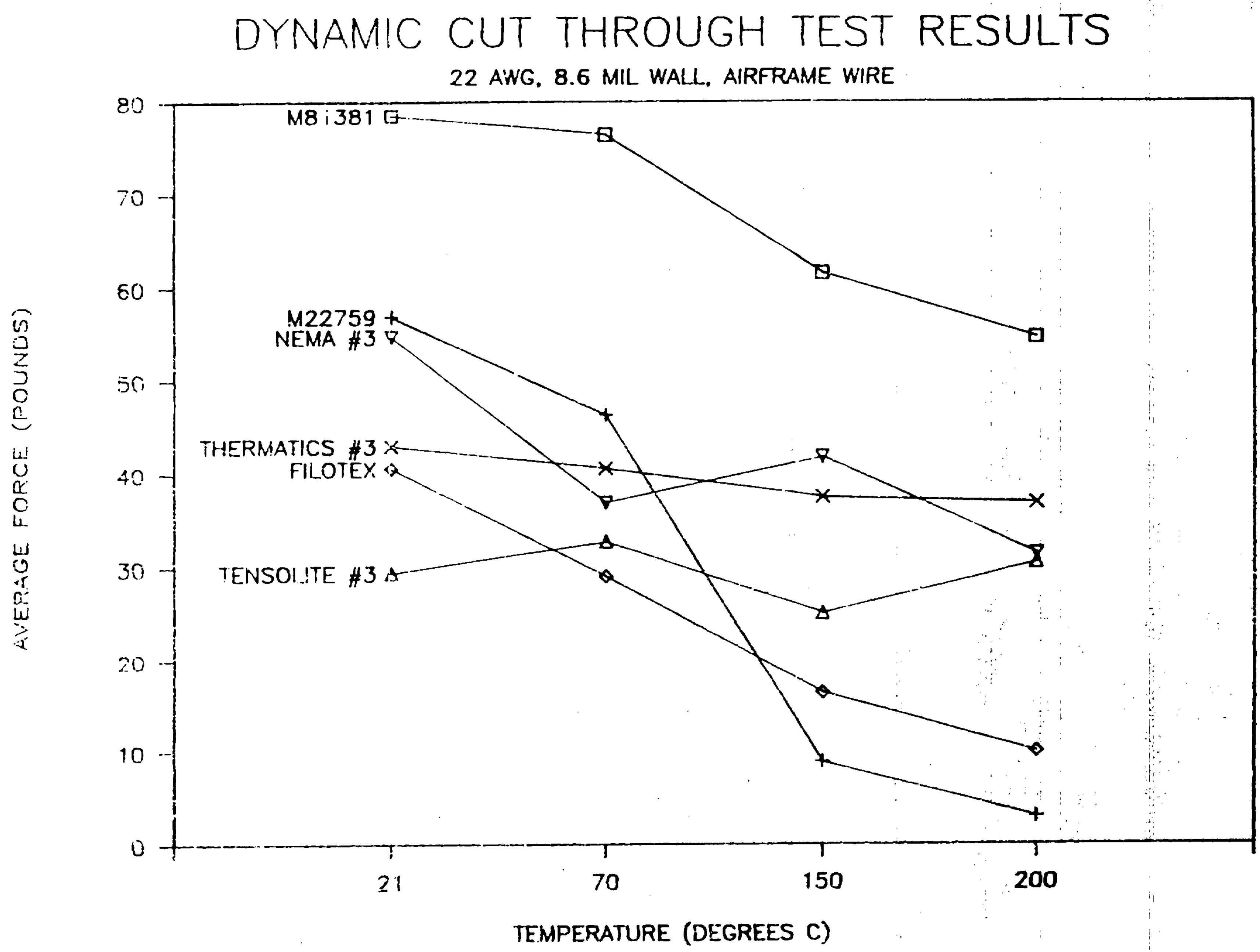


FIGURE 5.65 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

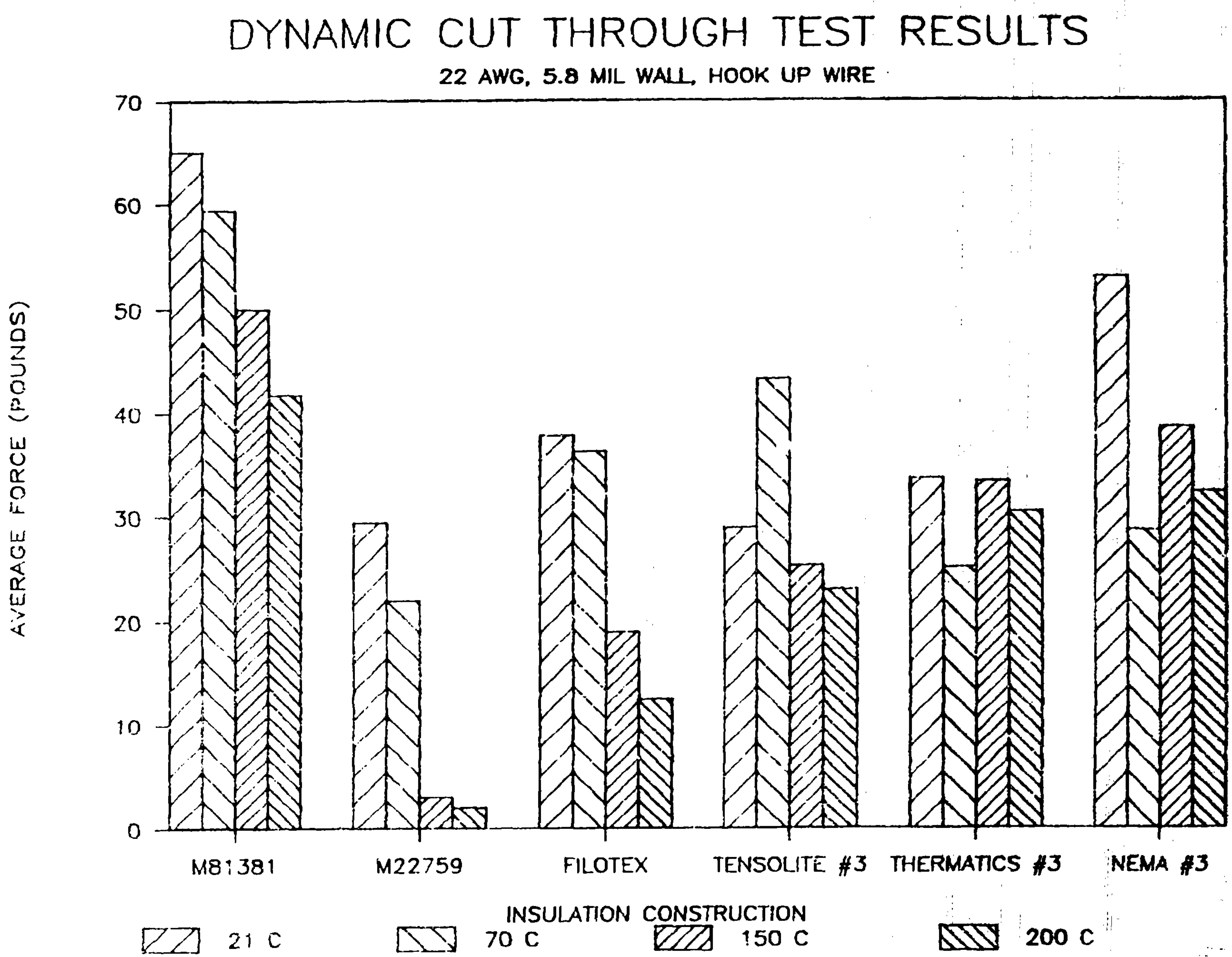


FIGURE 5.66 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

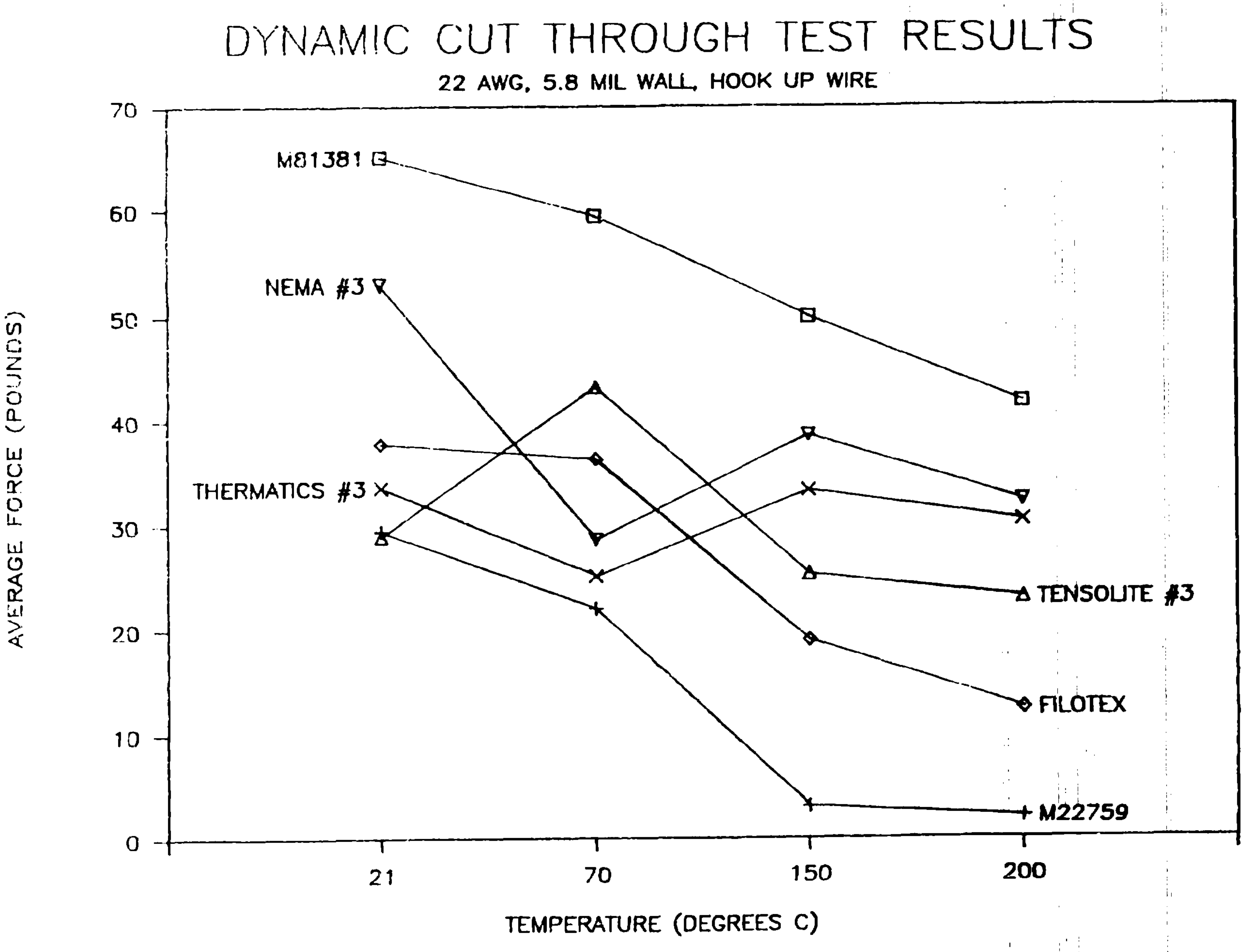


FIGURE 5.67 - DYNAMIC CUT THROUGH TEST RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

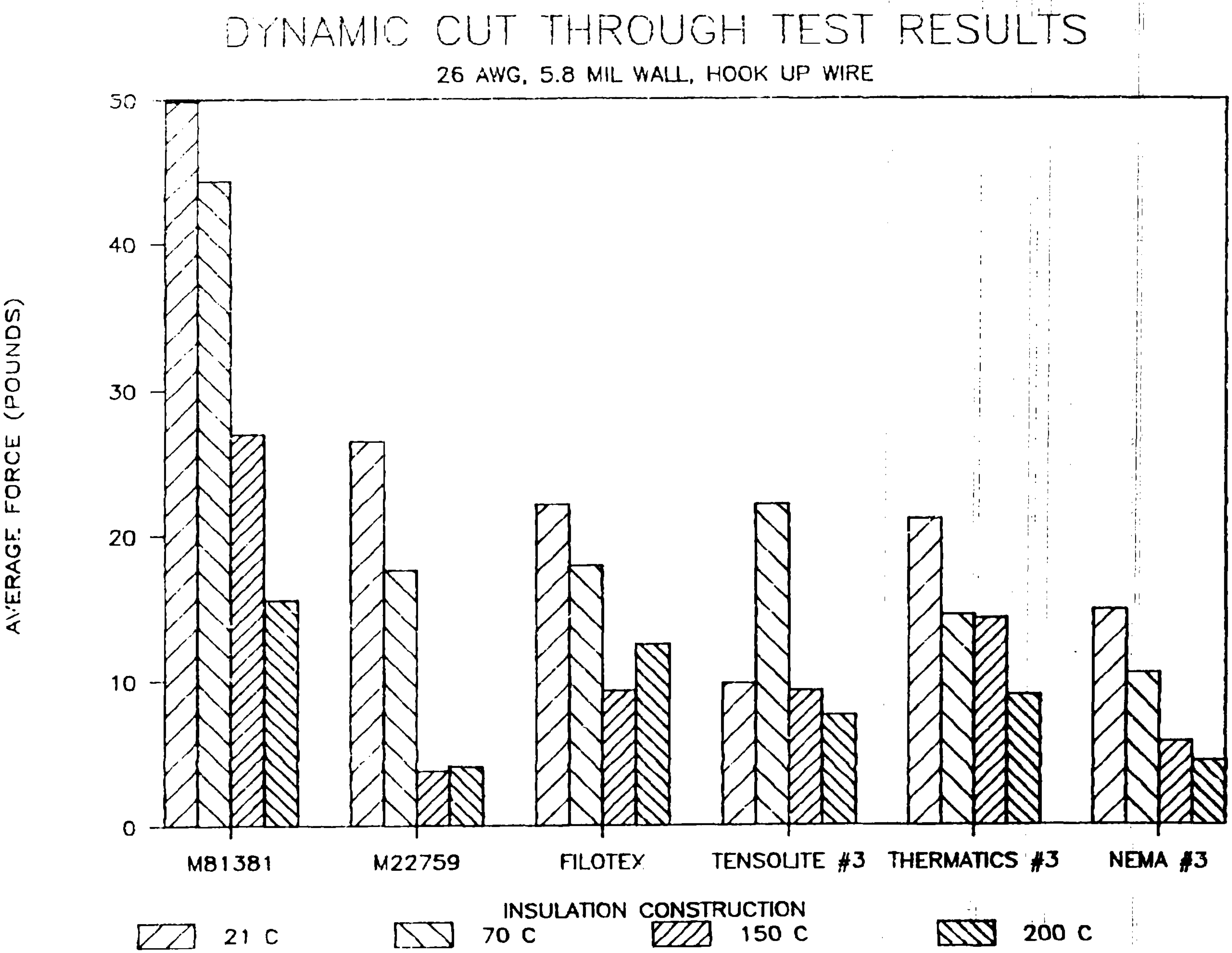


FIGURE 5.68 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

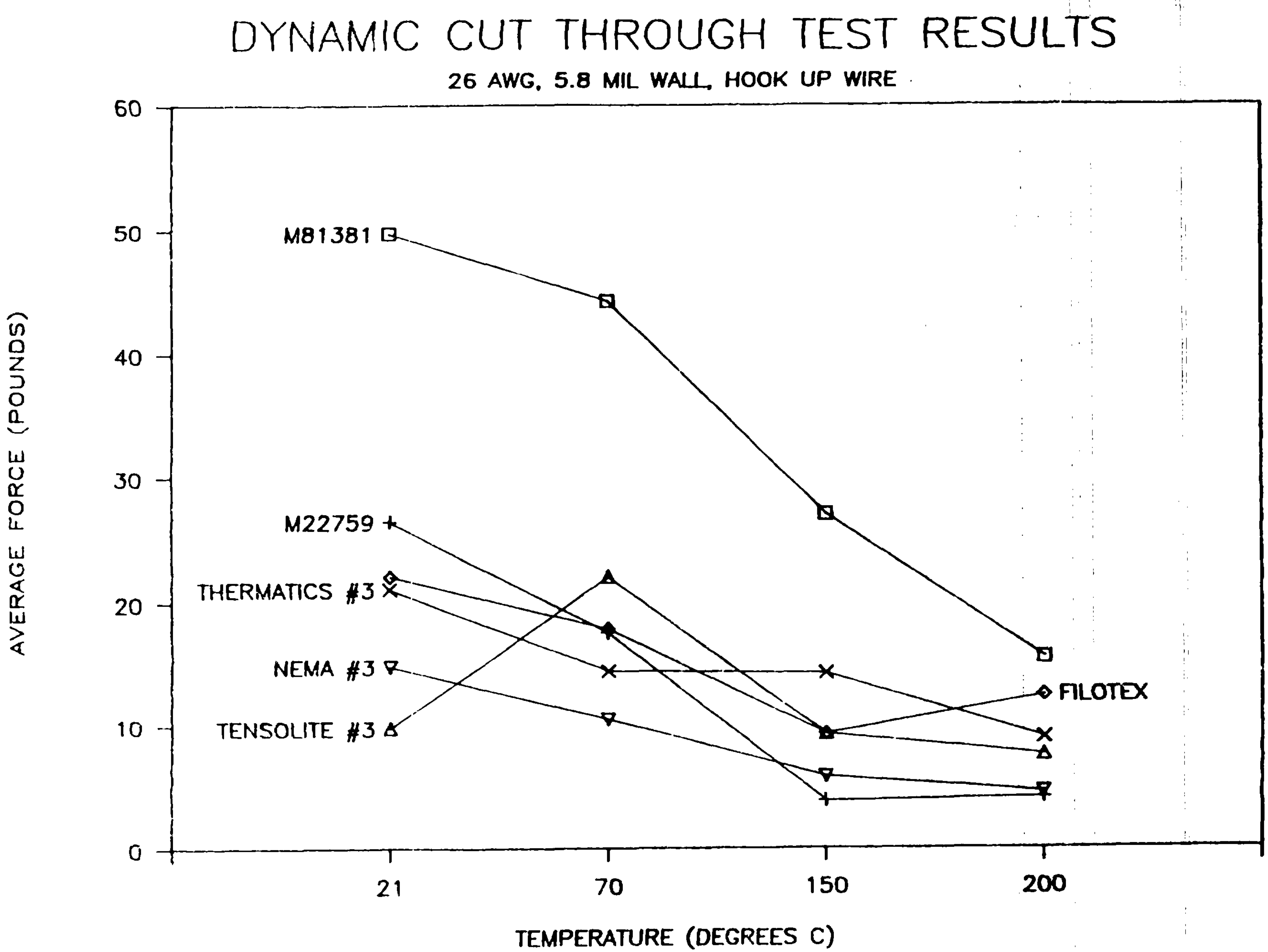


FIGURE 5.69 - DYNAMIC CUT THROUGH TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

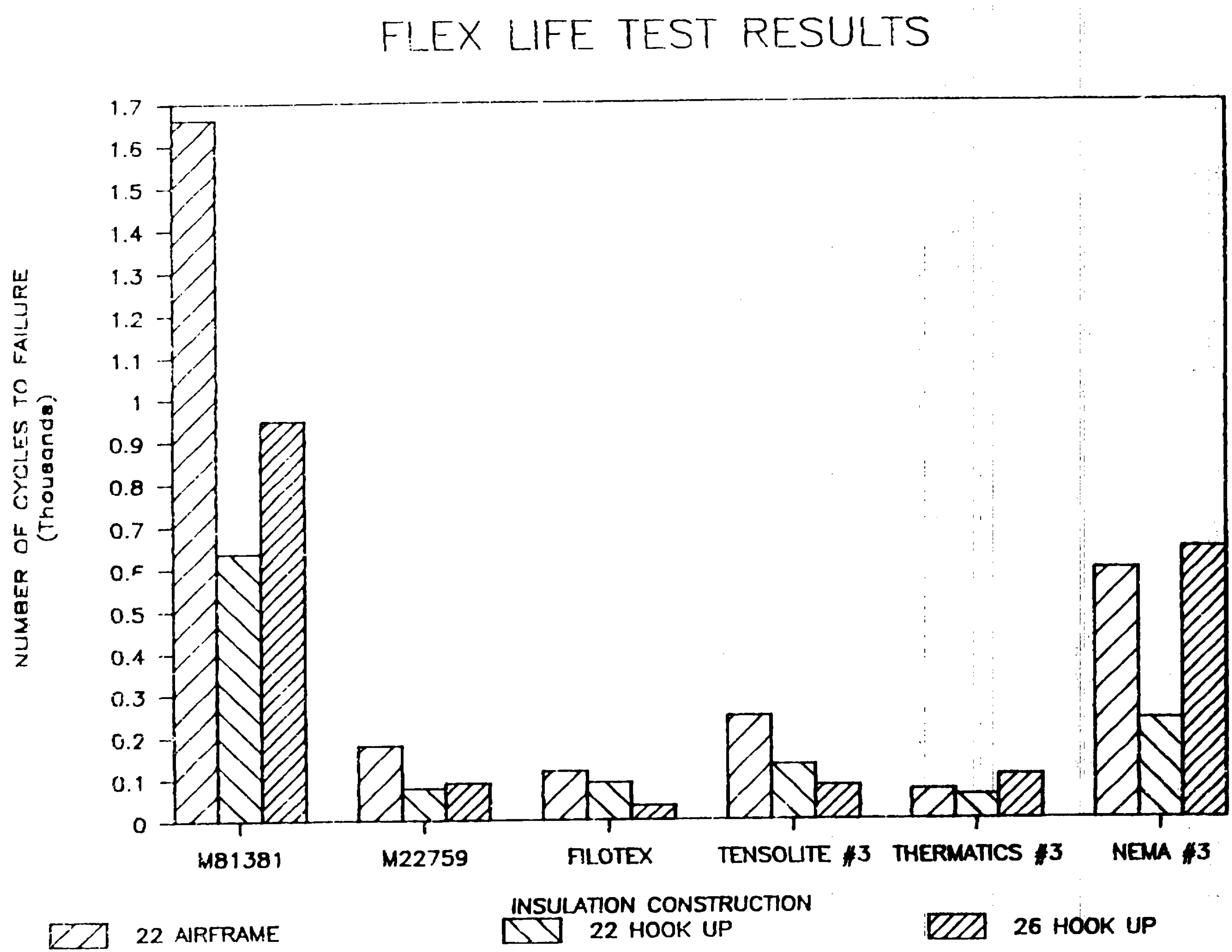


FIGURE 5.70 - FLEX LIFE TEST RESULTS

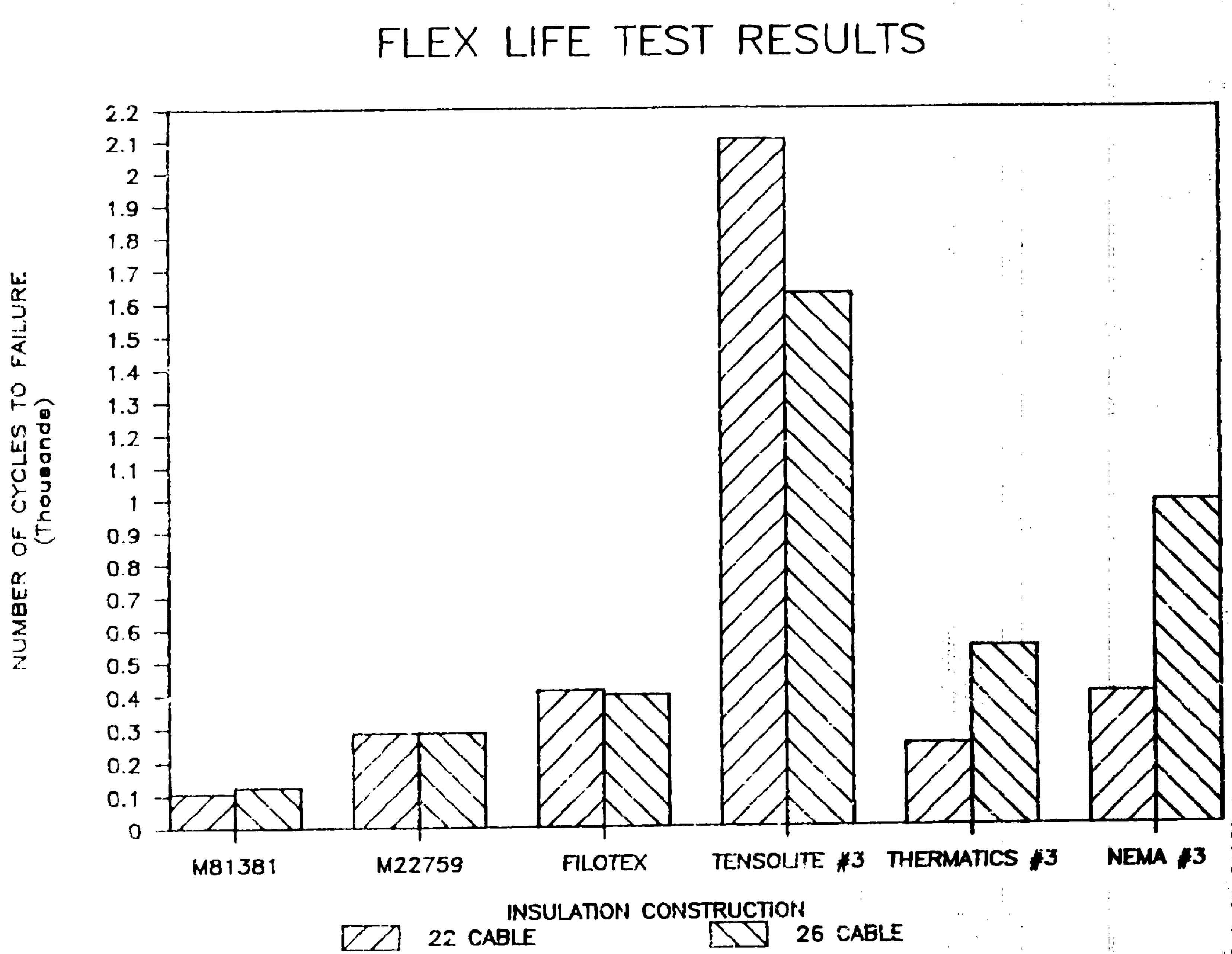


FIGURE 5.71 - FLEX LIFE TEST RESULTS

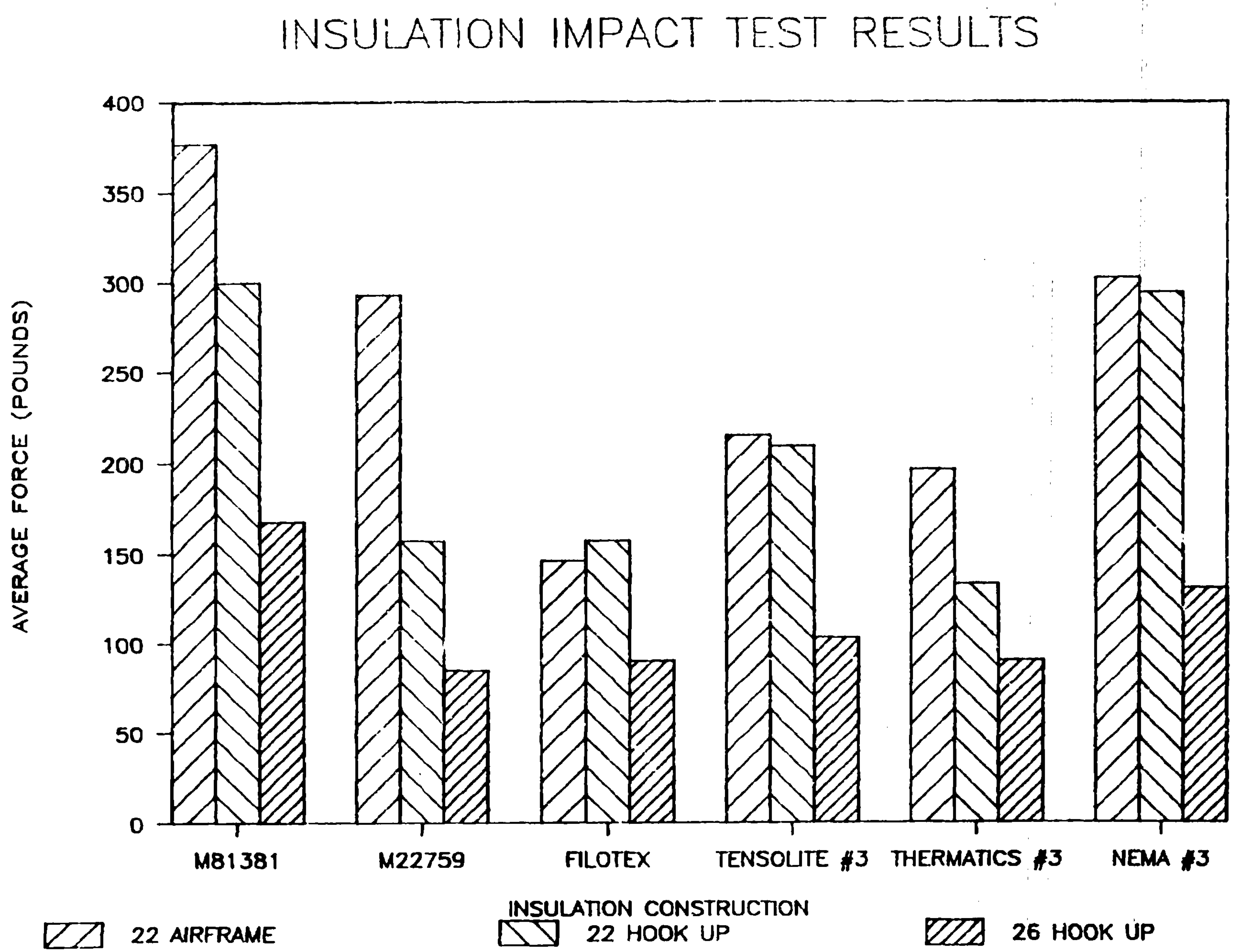


FIGURE 5.72 - INSULATION IMPACT TEST RESULTS

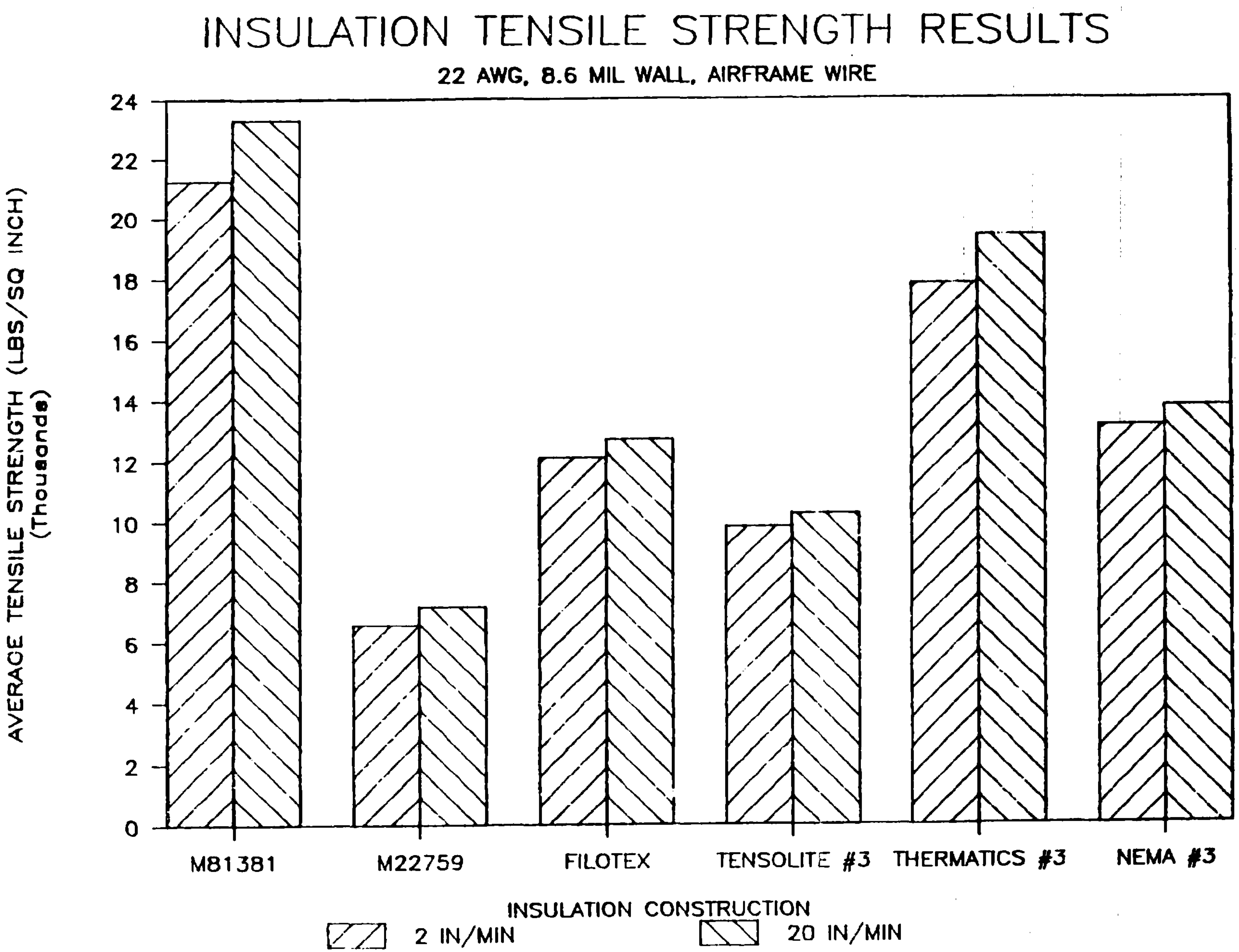


FIGURE 5.76 - INSULATION TENSILE STRENGTH RESULTS,
22AWG, 8.6 MIL WALL, AIRFRAME WIRE

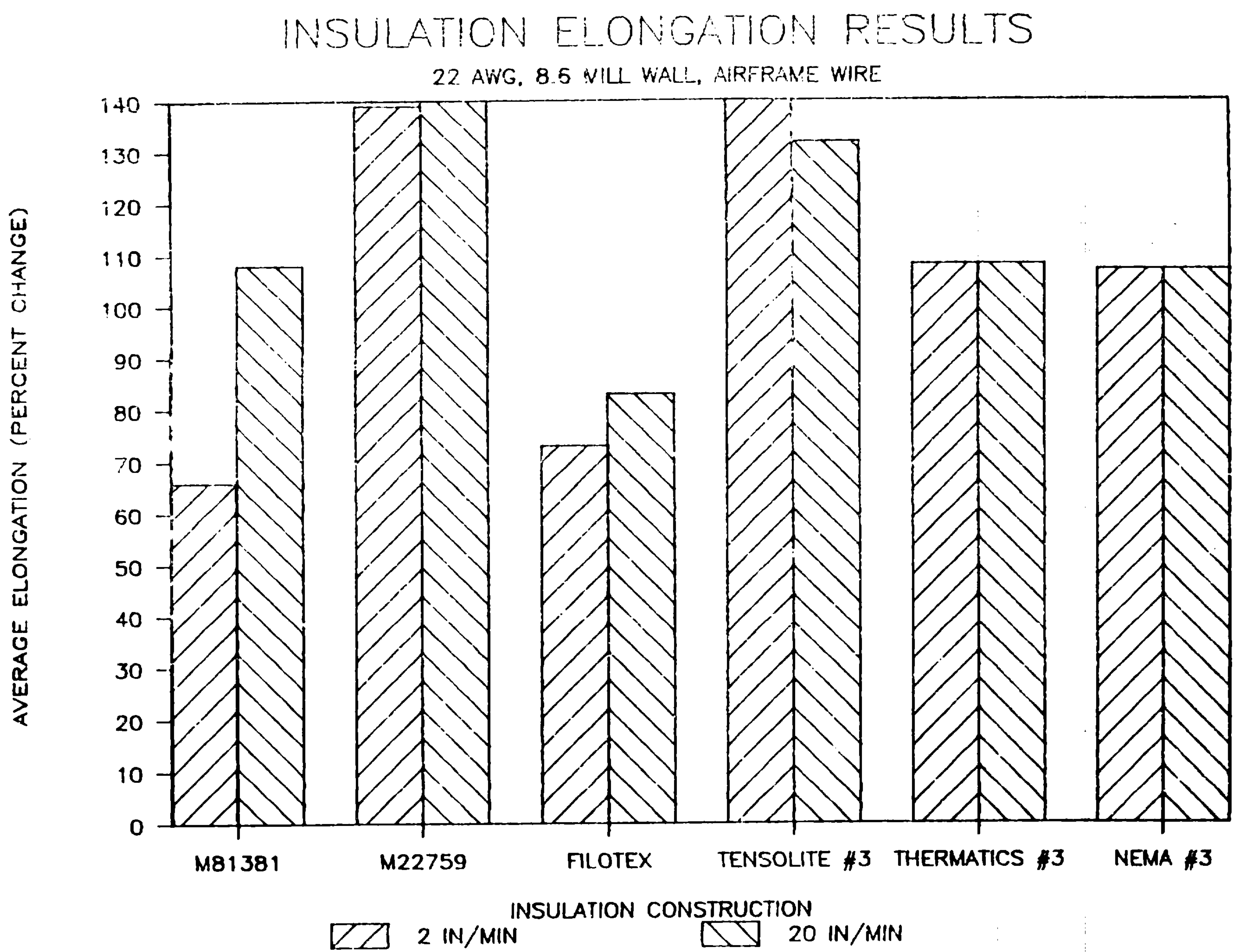


FIGURE 5.77 - INSULATION ELONGATION RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

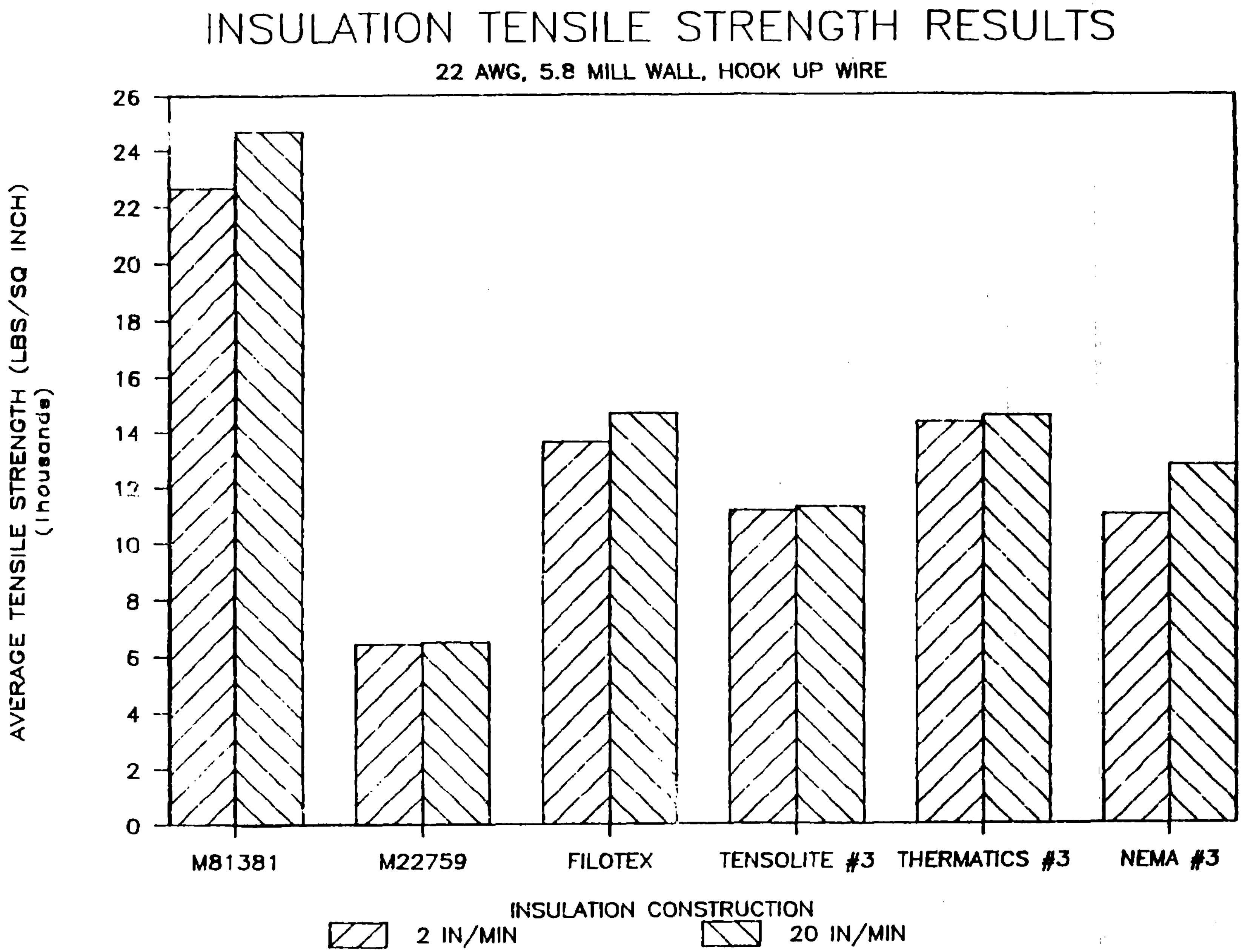


FIGURE 5.78 - INSULATION TENSILE STRENGTH RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

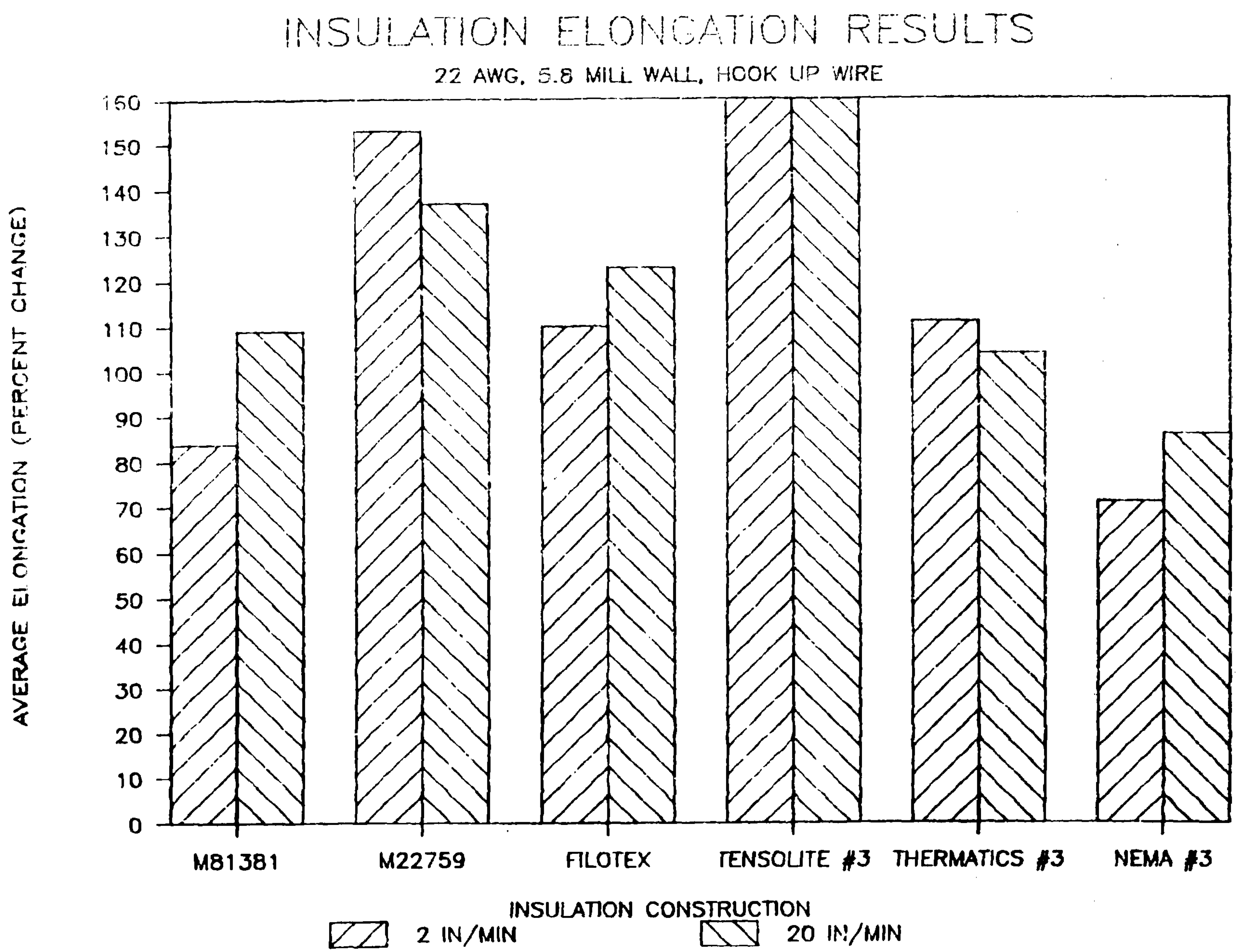


FIGURE 5.79 - INSULATION ELONGATION RESULTS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

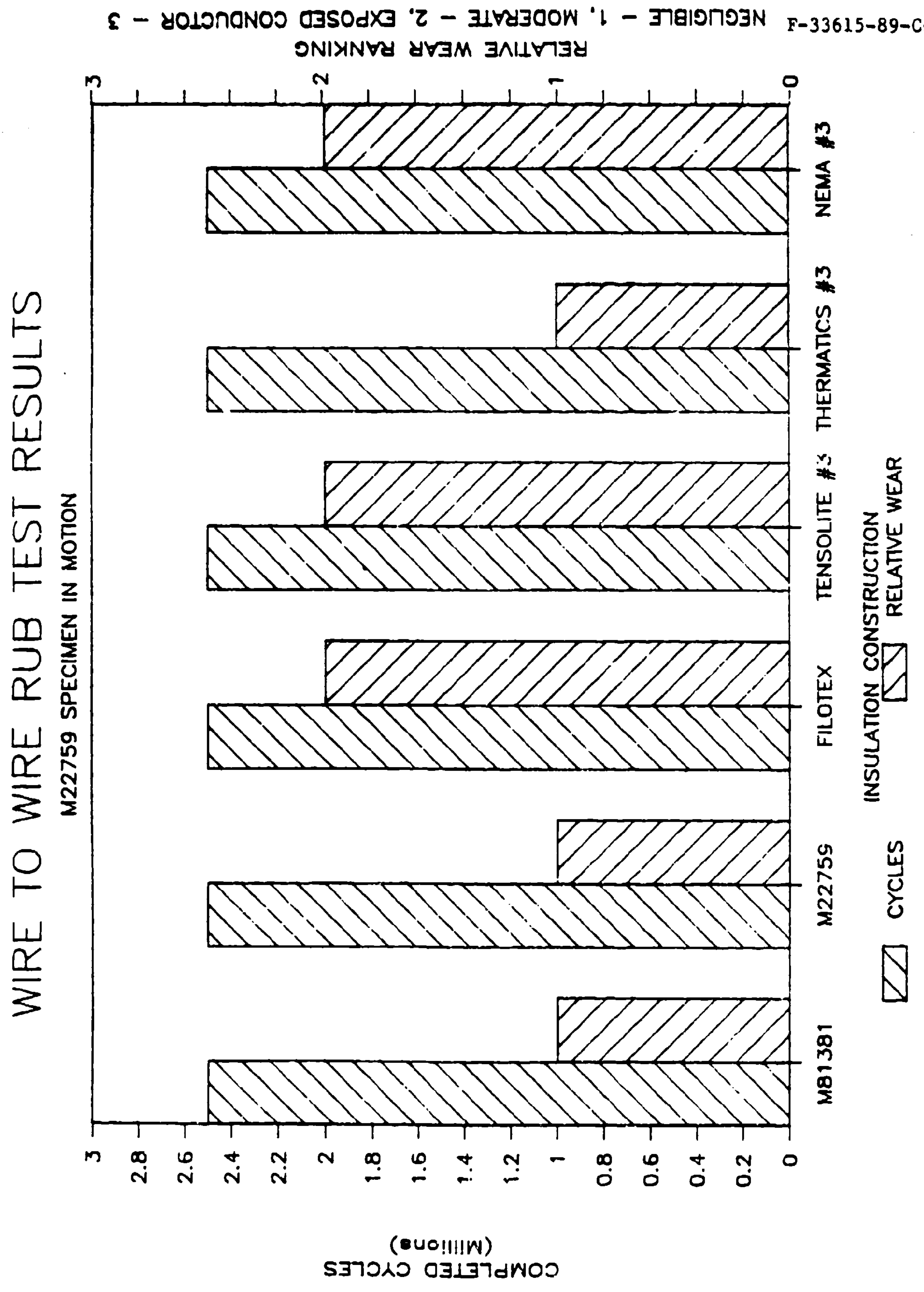


FIGURE 5.83 - WIRE TO WIRE RUB TEST RESULTS, M22759 SPECIMEN IN MOTION

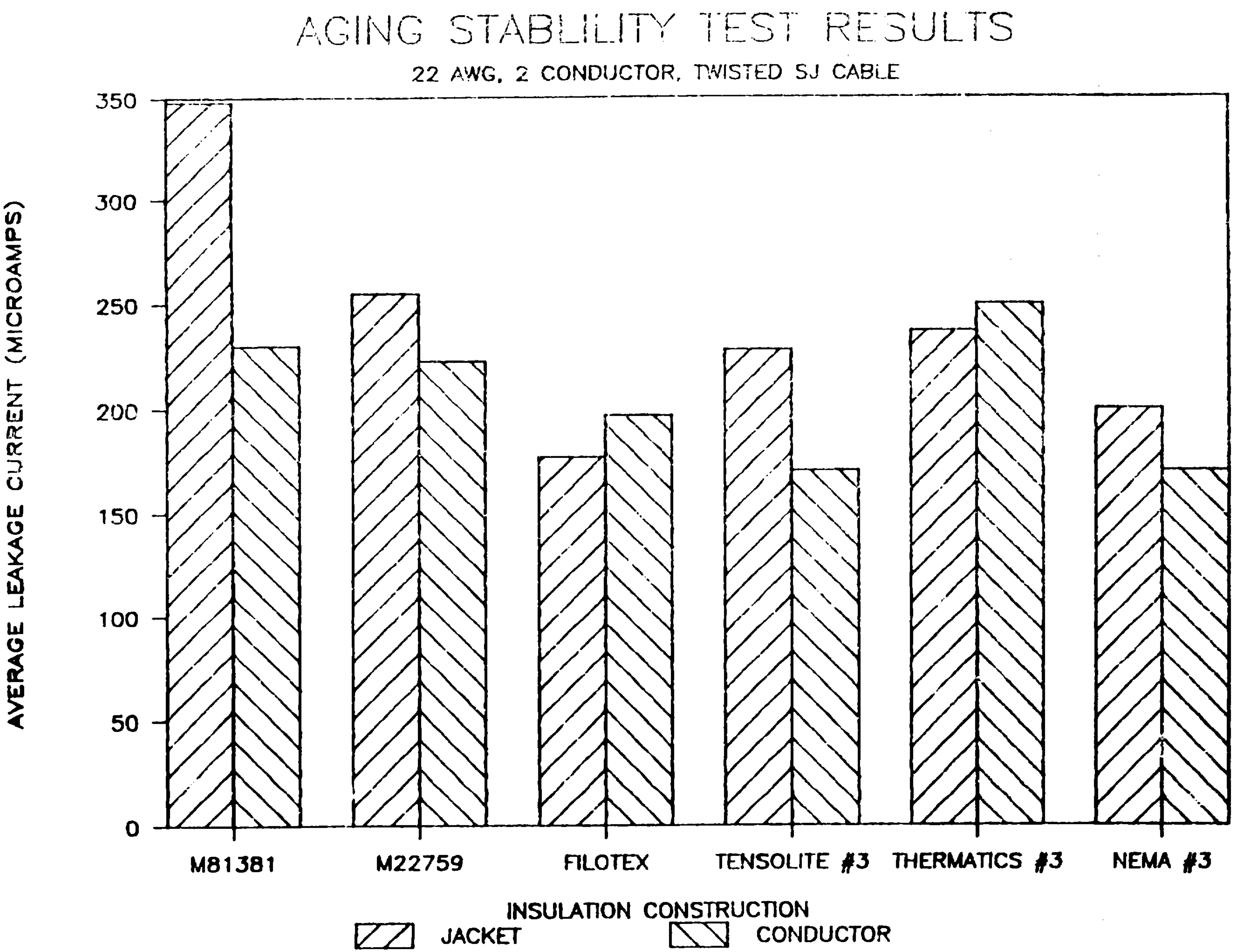


FIGURE 5.86 - AGING STABILITY TEST RESULTS,
22AWG, 2 CONDUCTOR, TWISTED SJ CABLE

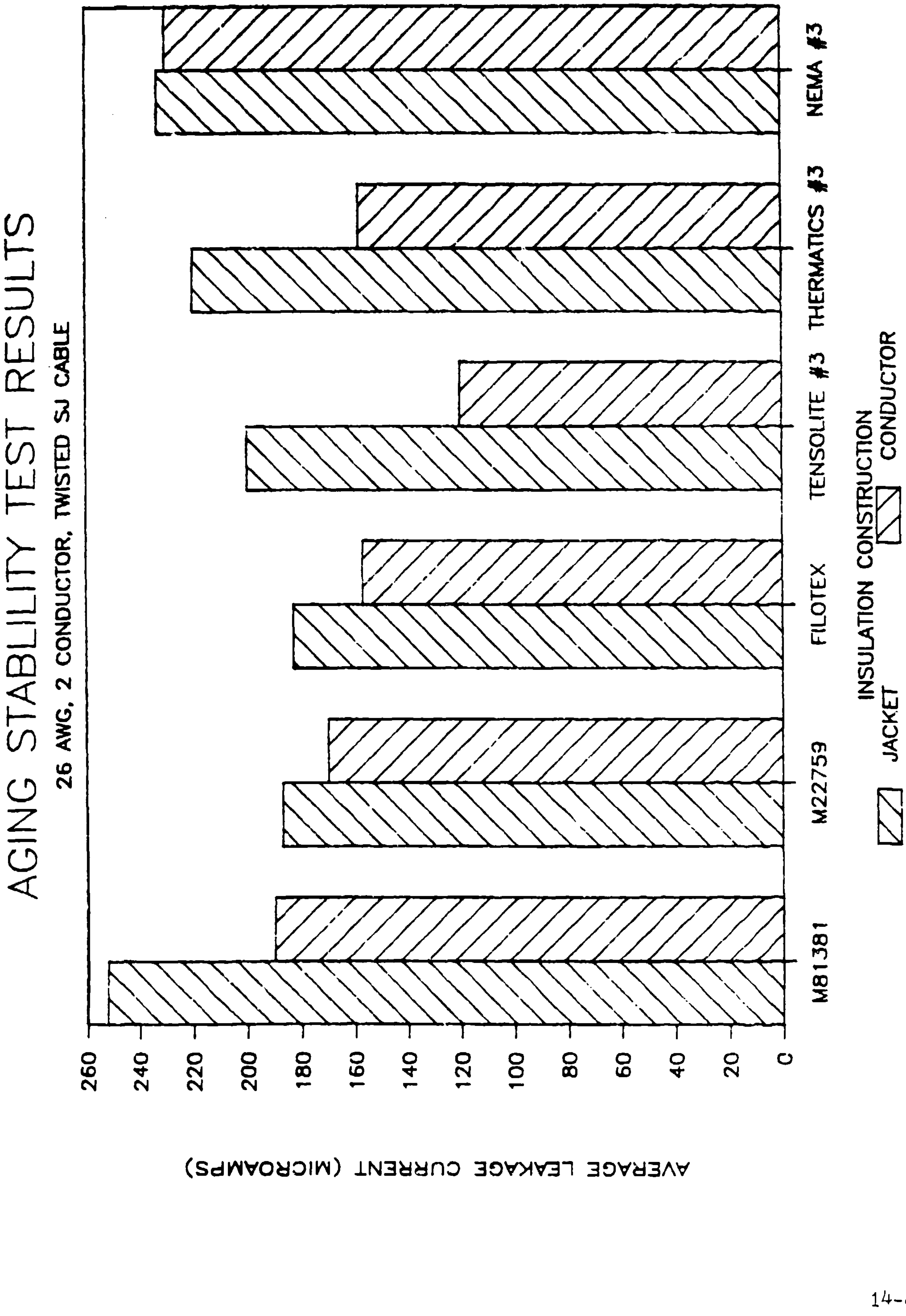


FIGURE 5.87 - AGING STABILITY TEST RESULTS,
26AWG, 2 CONDUCTOR, TWISTED SJ CABLE

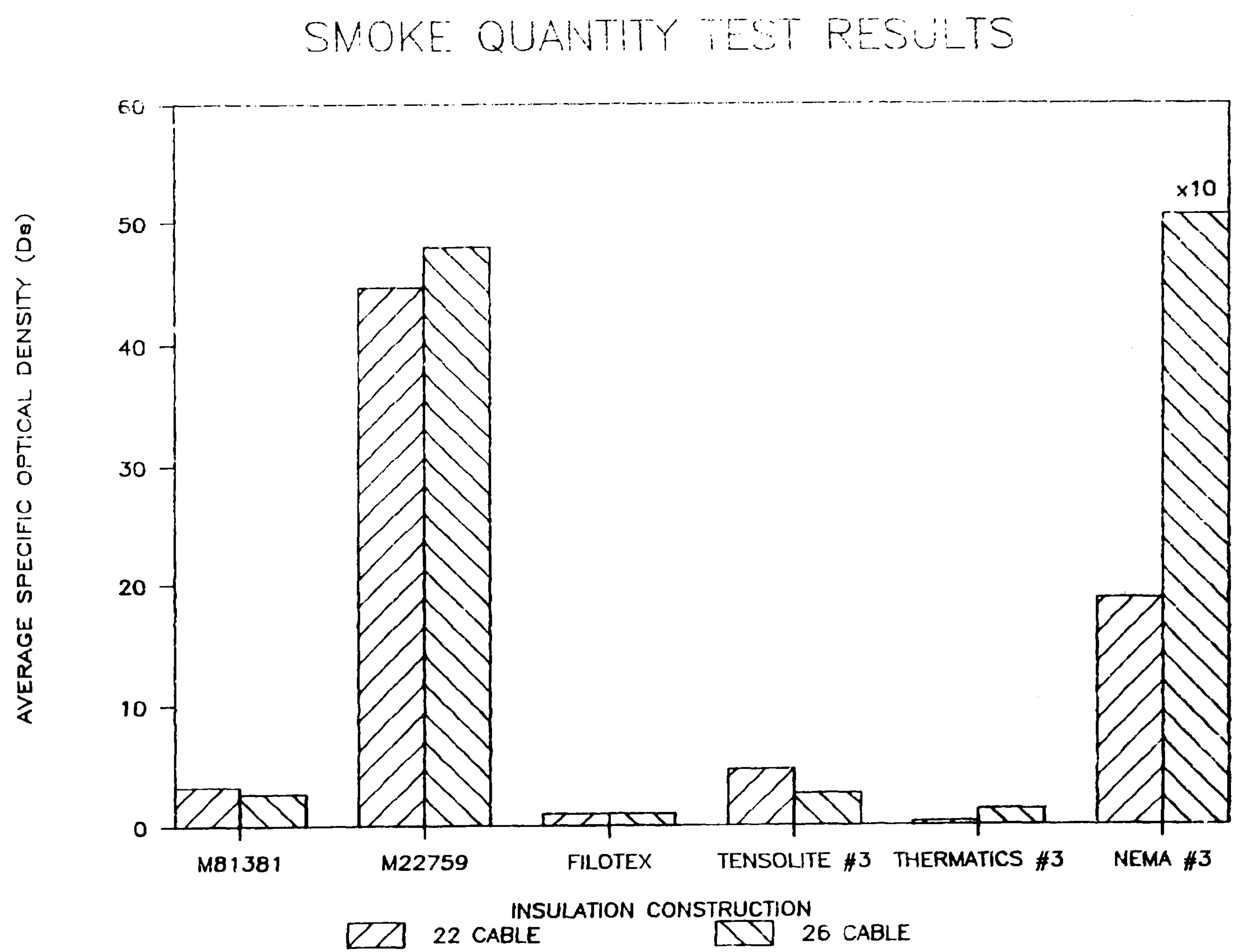


FIGURE 5.92 - SMOKE QUANTITY TEST RESULTS

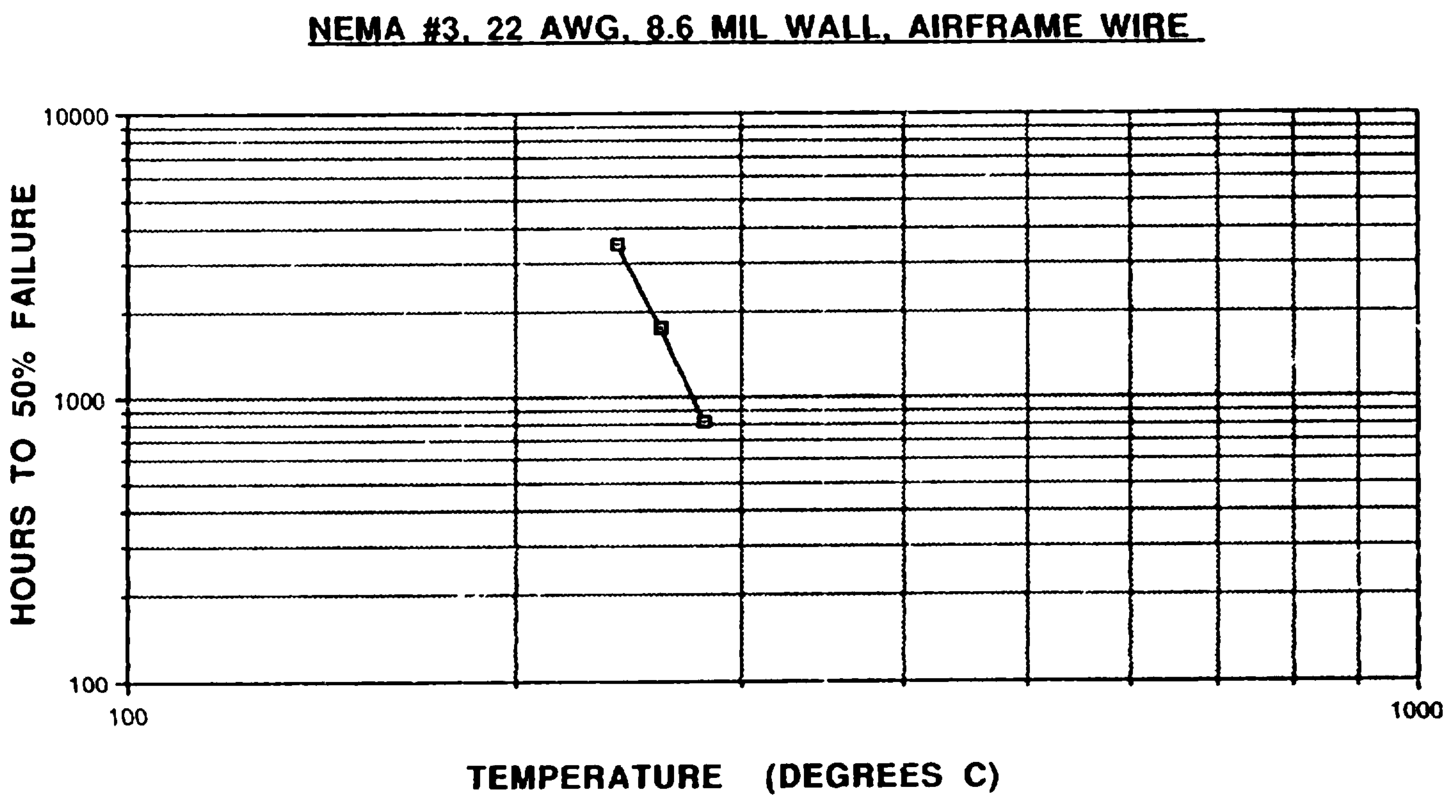


FIGURE 5.93 - THERMAL INDEX TEST RESULTS,
NEMA #3, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

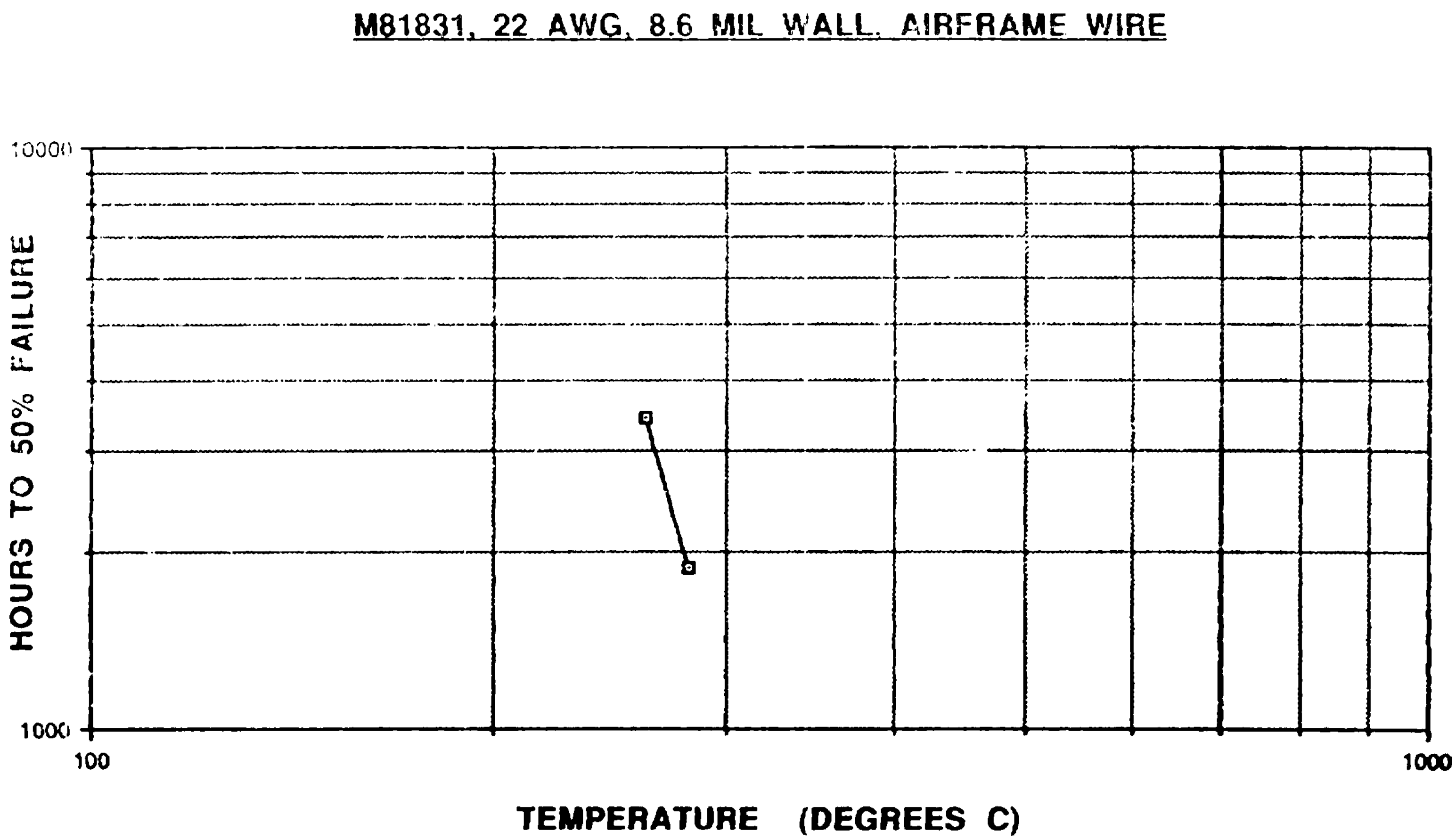


FIGURE 5.94 - THERMAL INDEX TEST RESULTS,
M81.:1, 22AWG, 8.6 MIL WALL, AIRFRAME WIPE

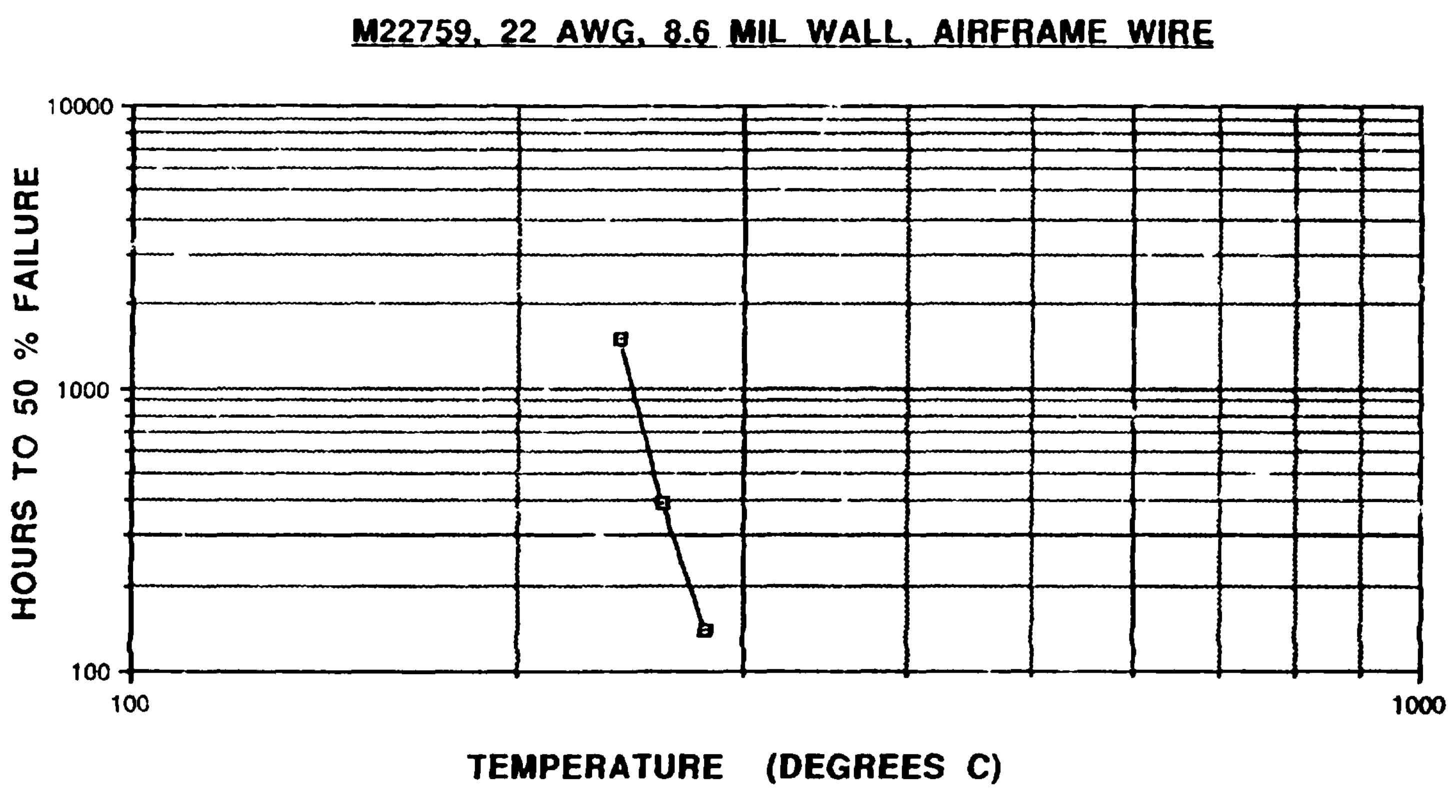


FIGURE 5.95 - THERMAL INDEX TEST RESULTS,
M22759, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

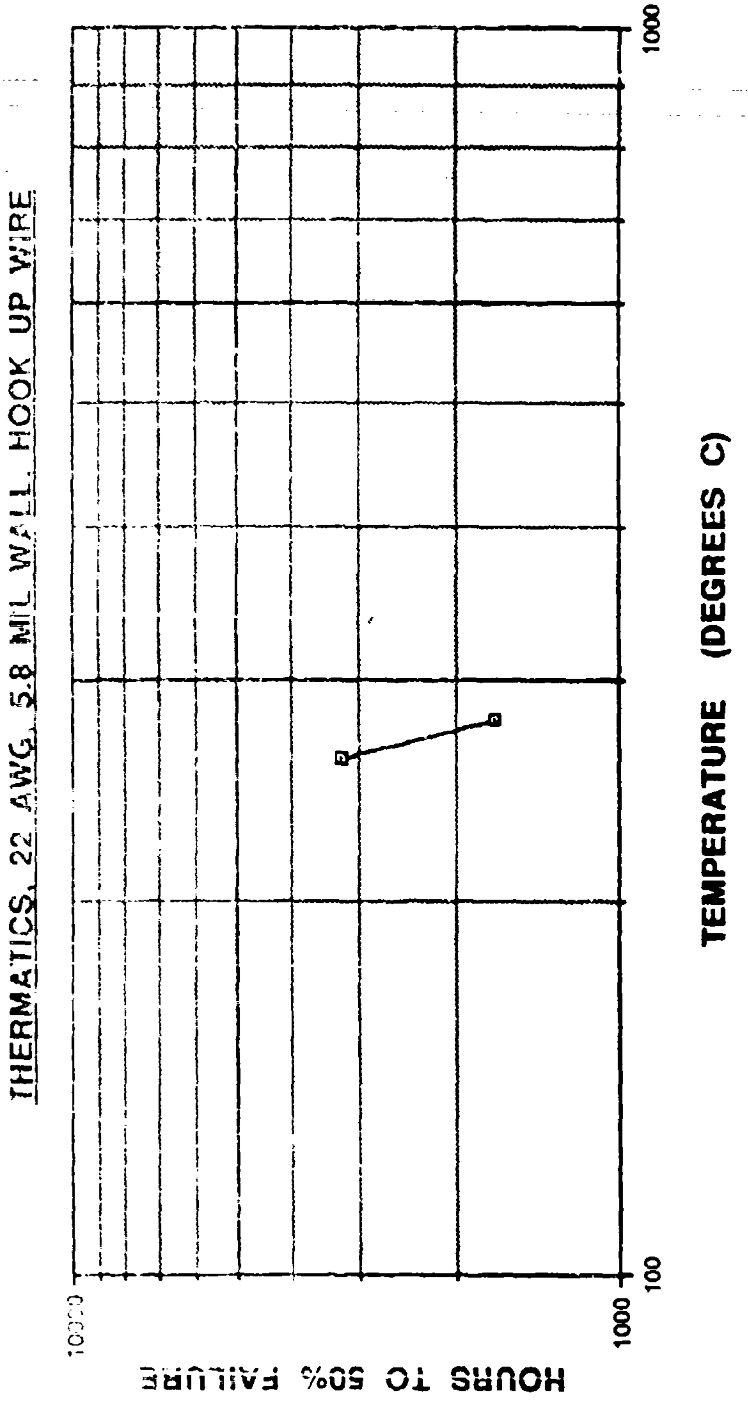


FIGURE 5.96 - THERMAL INDEX TEST RESULTS, THERMATICS, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

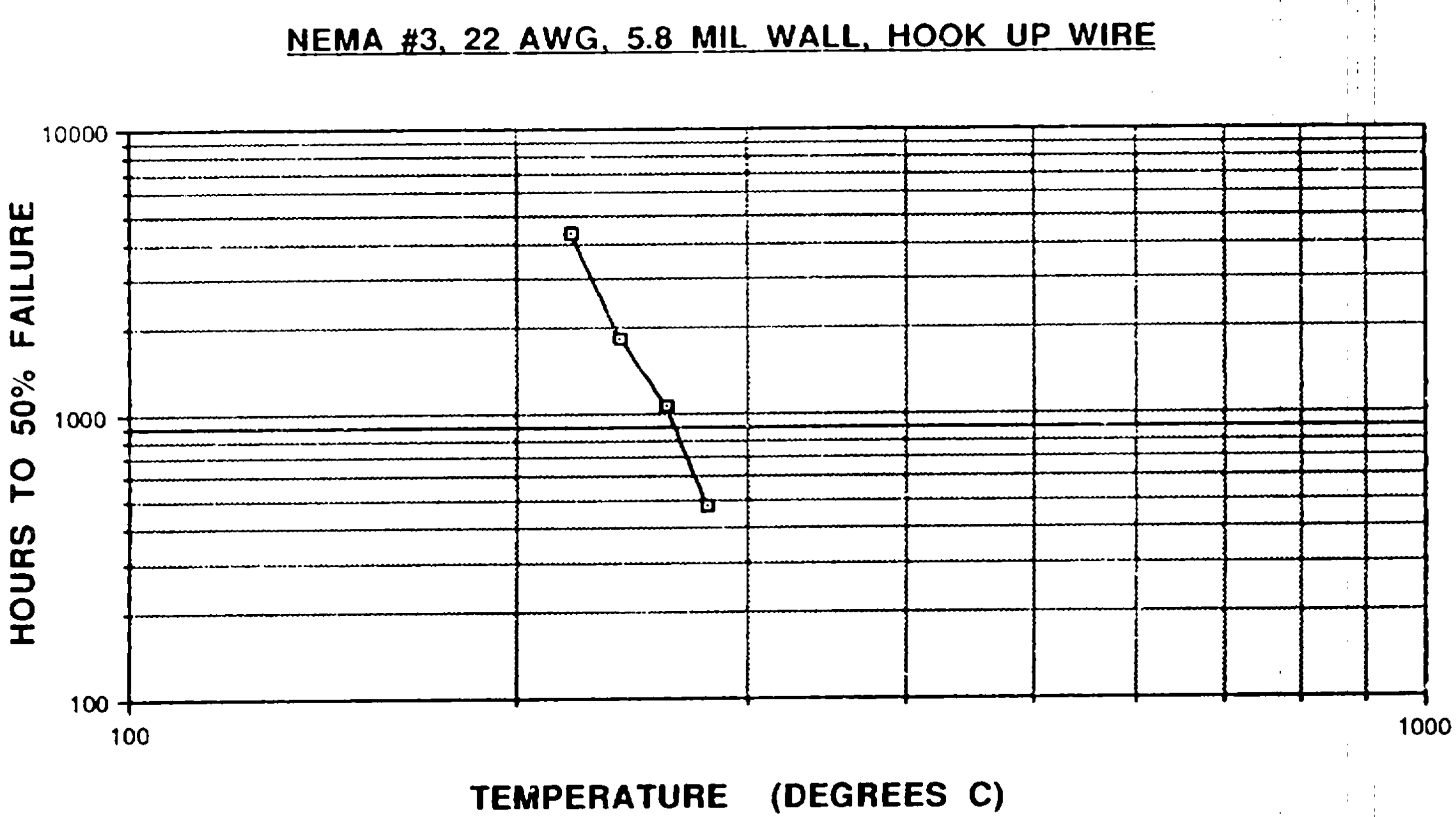


FIGURE 5.97 - THERMAL INDEX TEST RESULTS, NEMA #3, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

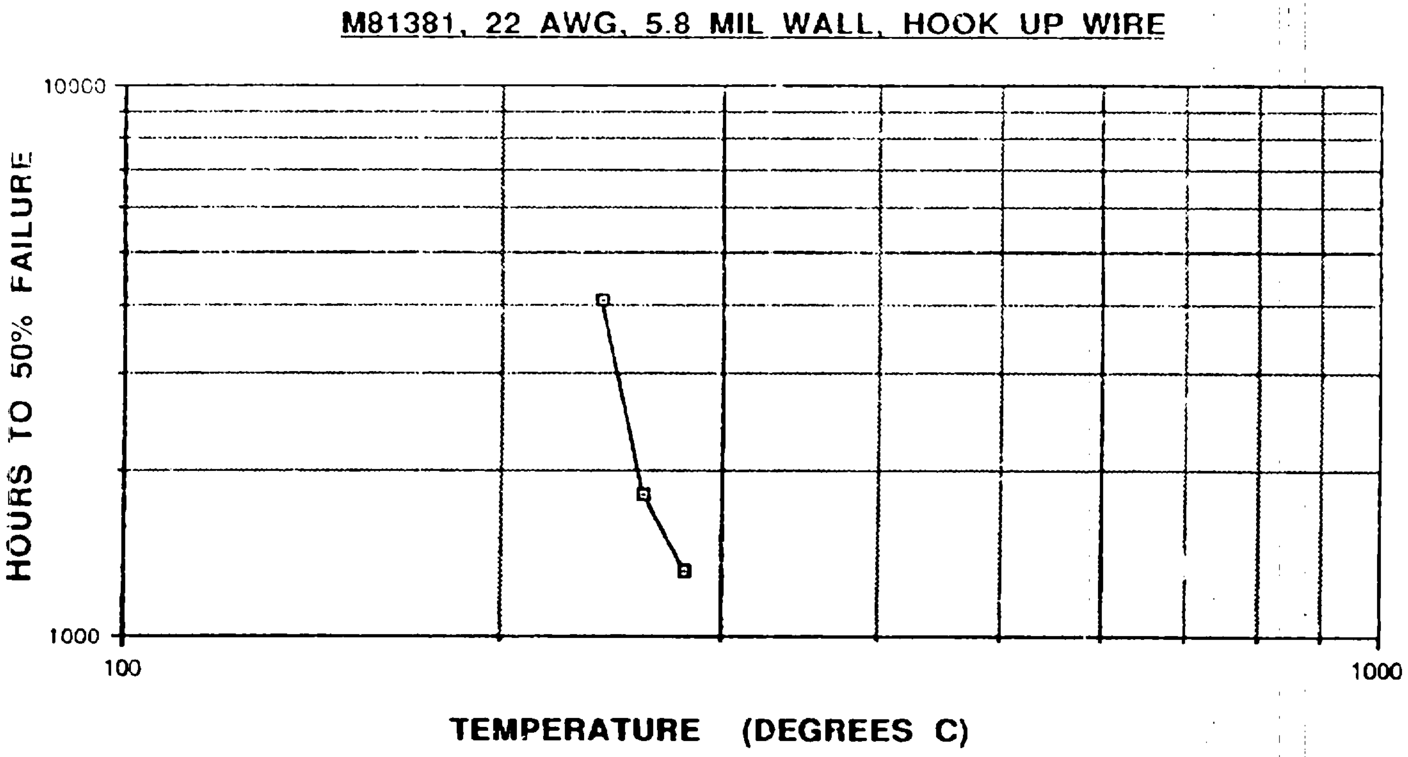


FIGURE 5.98 - THERMAL INDEX TEST RESULTS, M81381, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

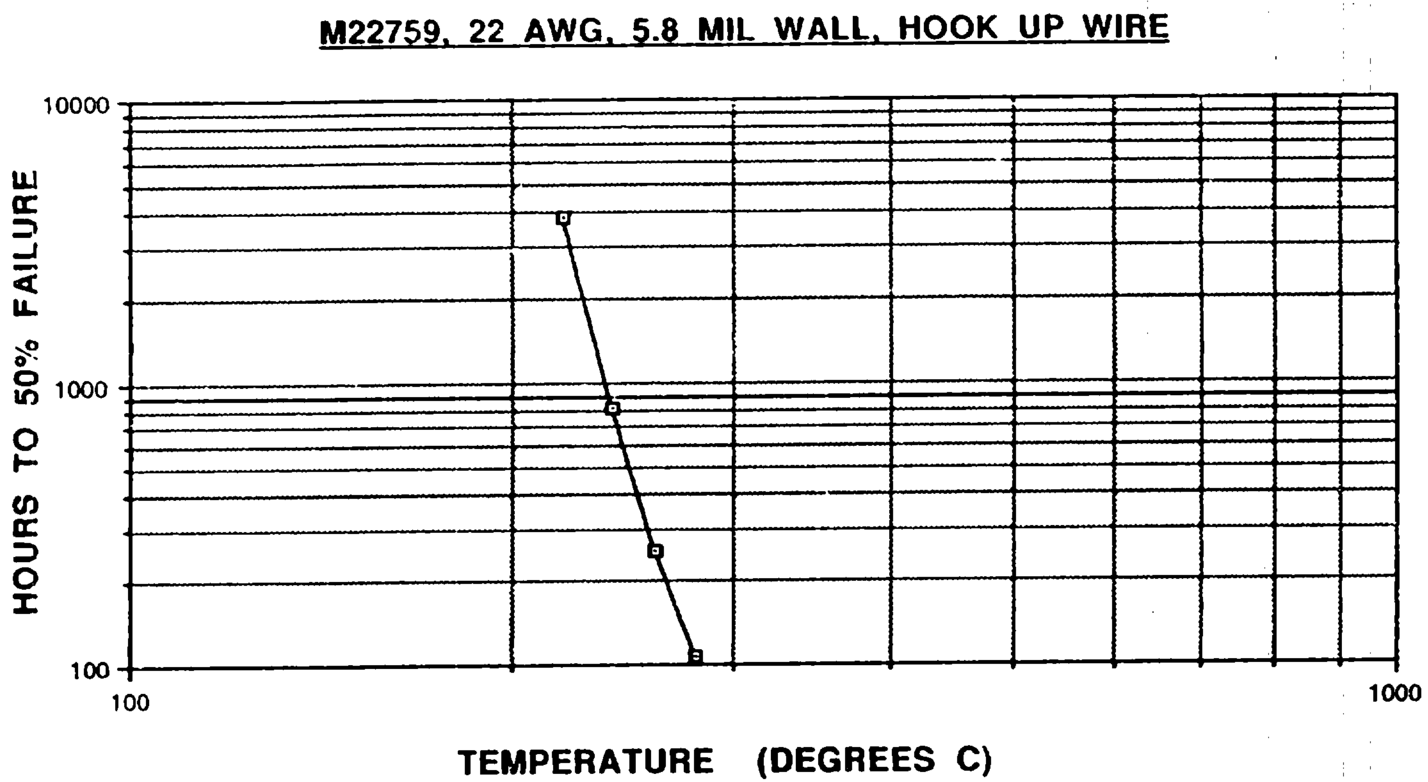


FIGURE 5.99 - THERMAL INDEX TEST RESULTS, M22759, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

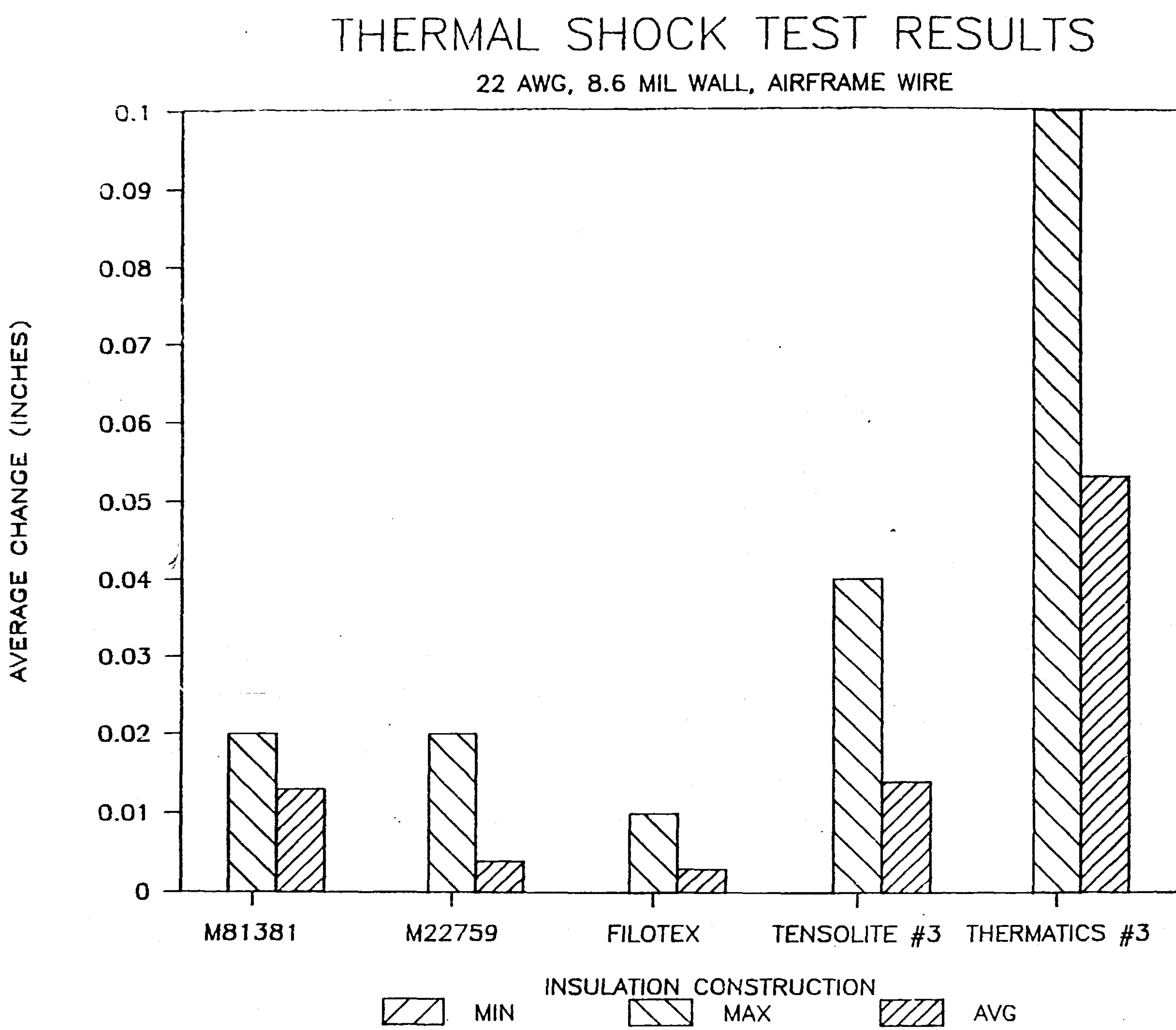


FIGURE 5.100 - THERMAL SHOCK TEST RESULTS, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

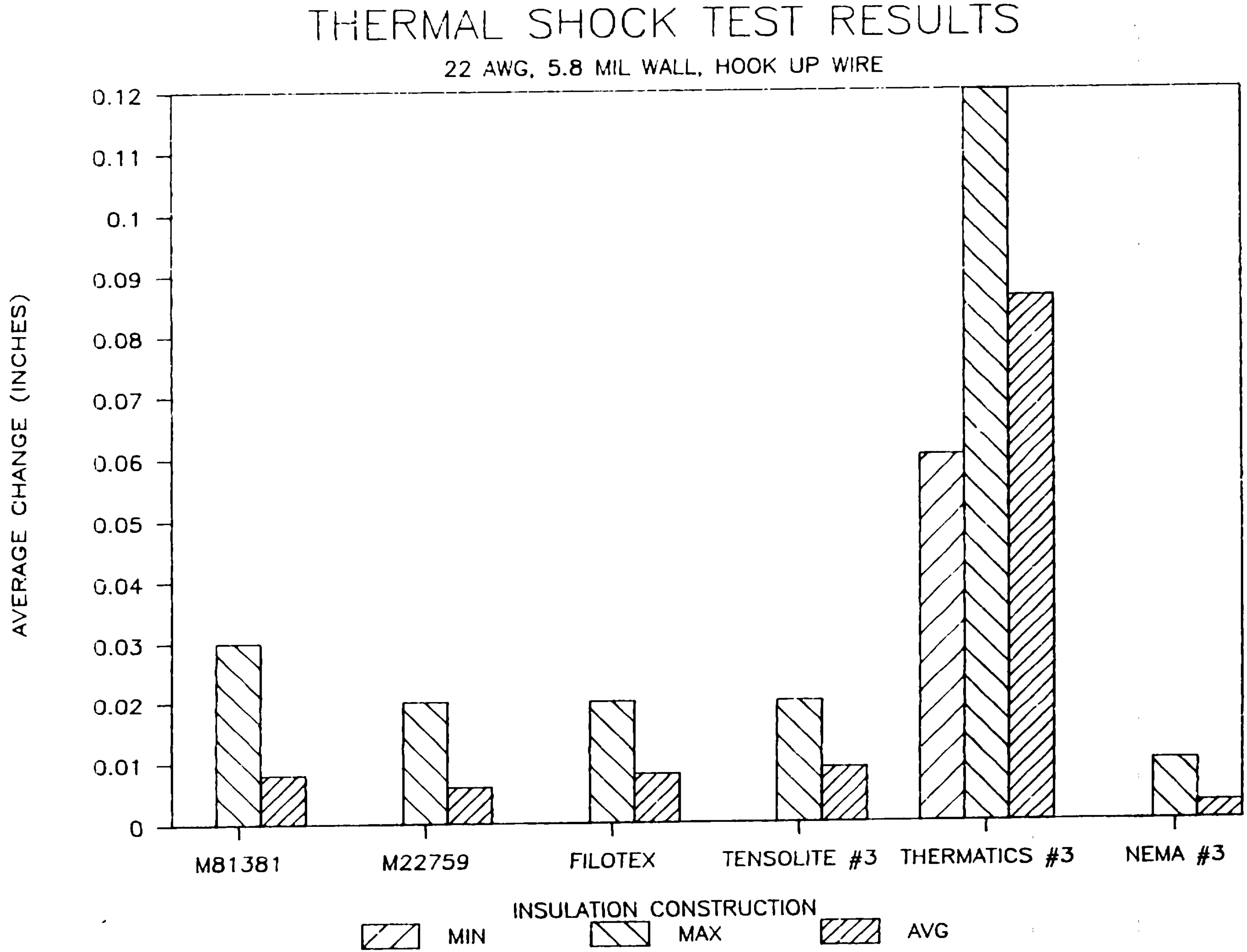


FIGURE 5.101 - THERMAL SHOCK TEST RESULTS, 22AWG, 5.8 MIL WALL HOOK UP WIRE

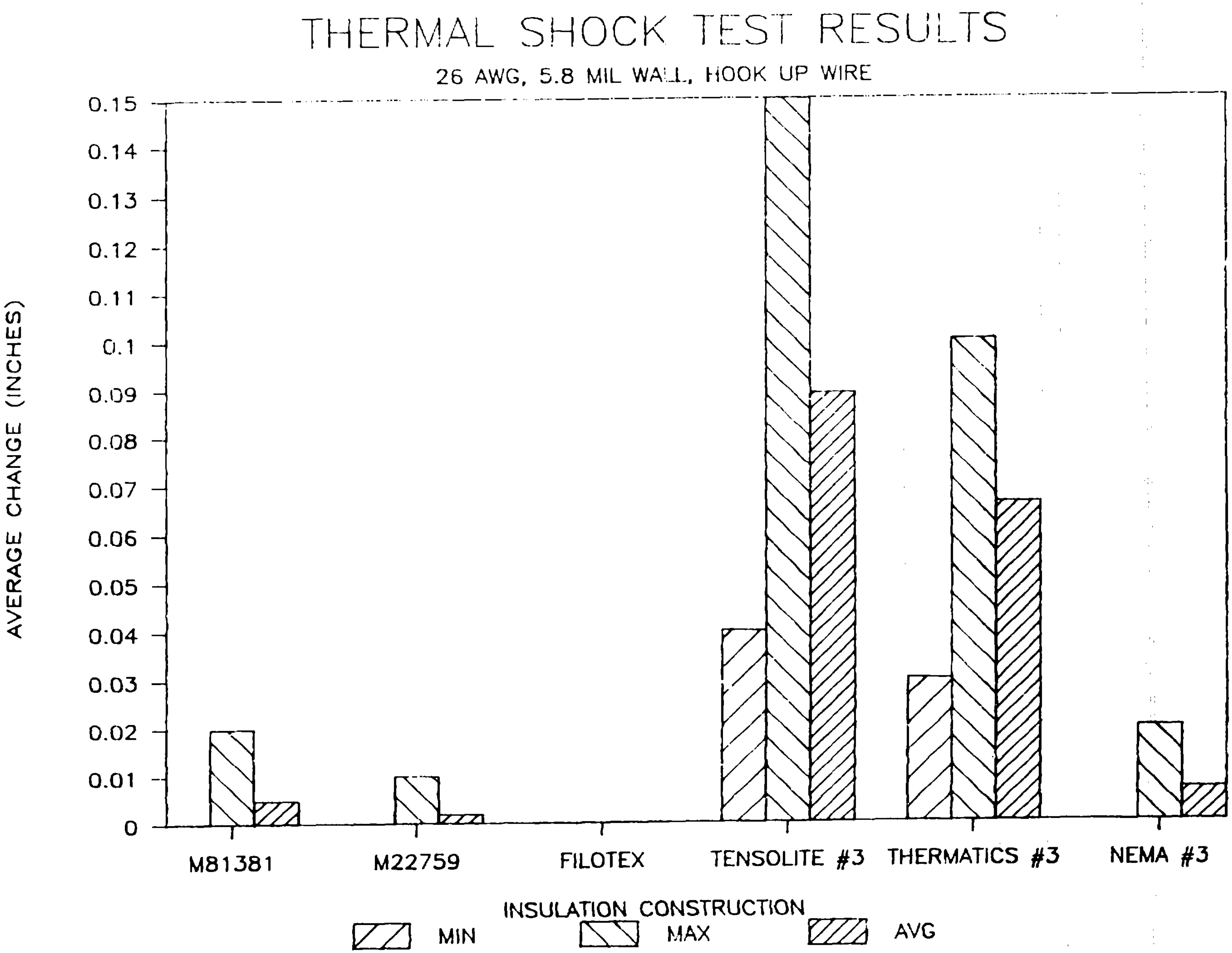


FIGURE 5.102 - THERMAL SHOCK TEST RESULTS, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

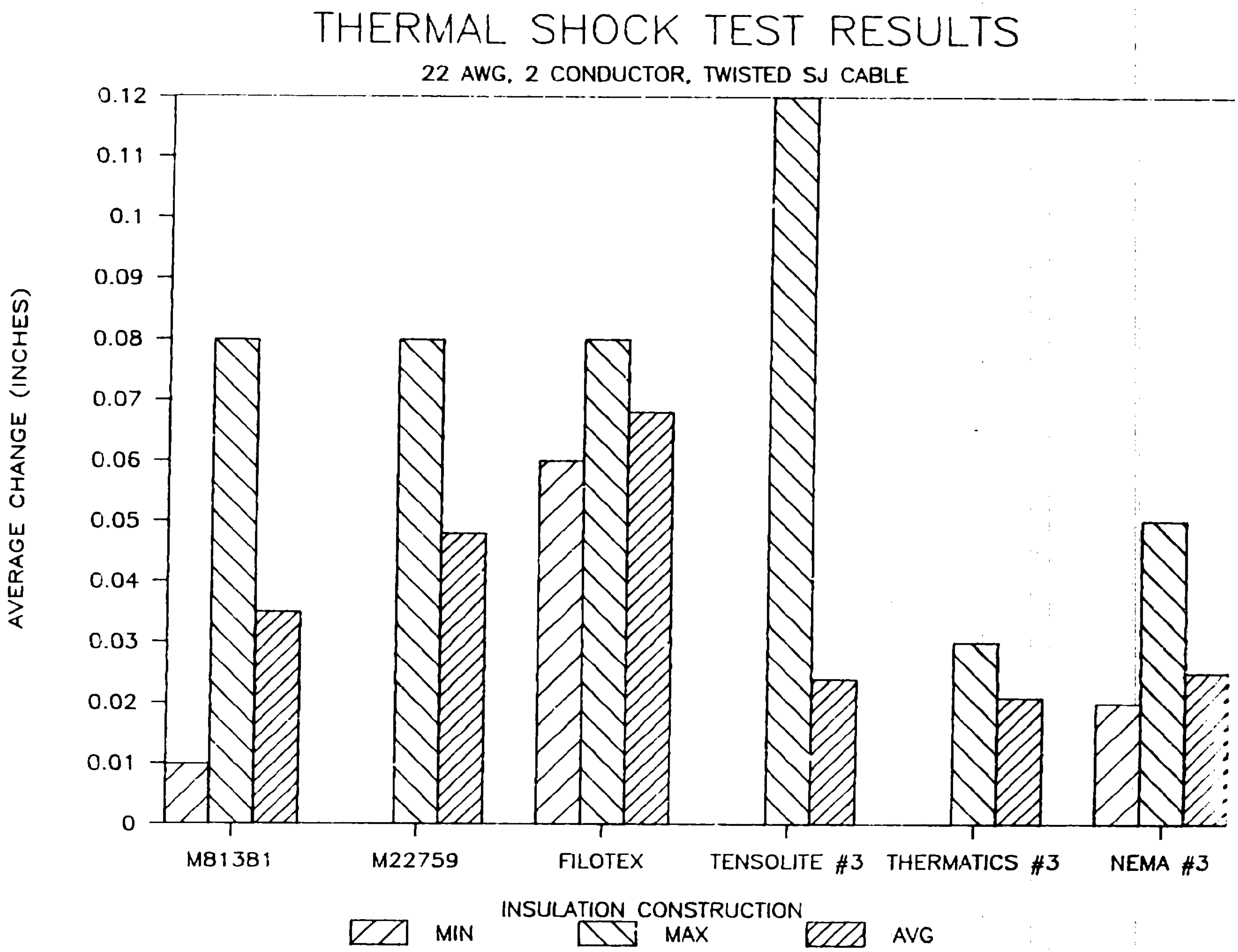


FIGURE 5.103 - THERMAL SHOCK TEST RESULTS, 22AWG, 2 CONDUCTOR, TWISTED SJ CABLE

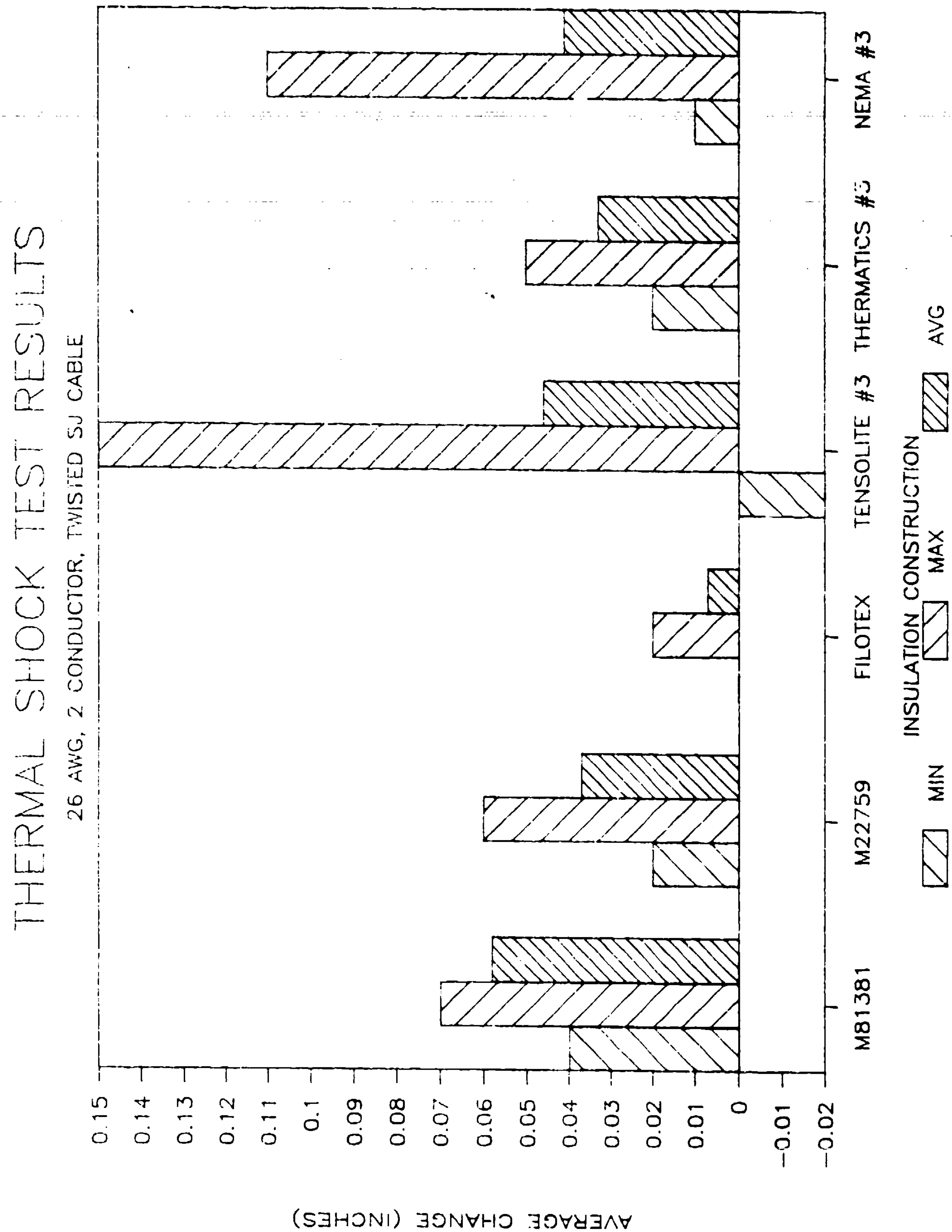


FIGURE 5.104 - THERMAL SHOCK TEST RESULTS, 26AWG, 2 CONDUCTOR, TWISTED SJ CABLE

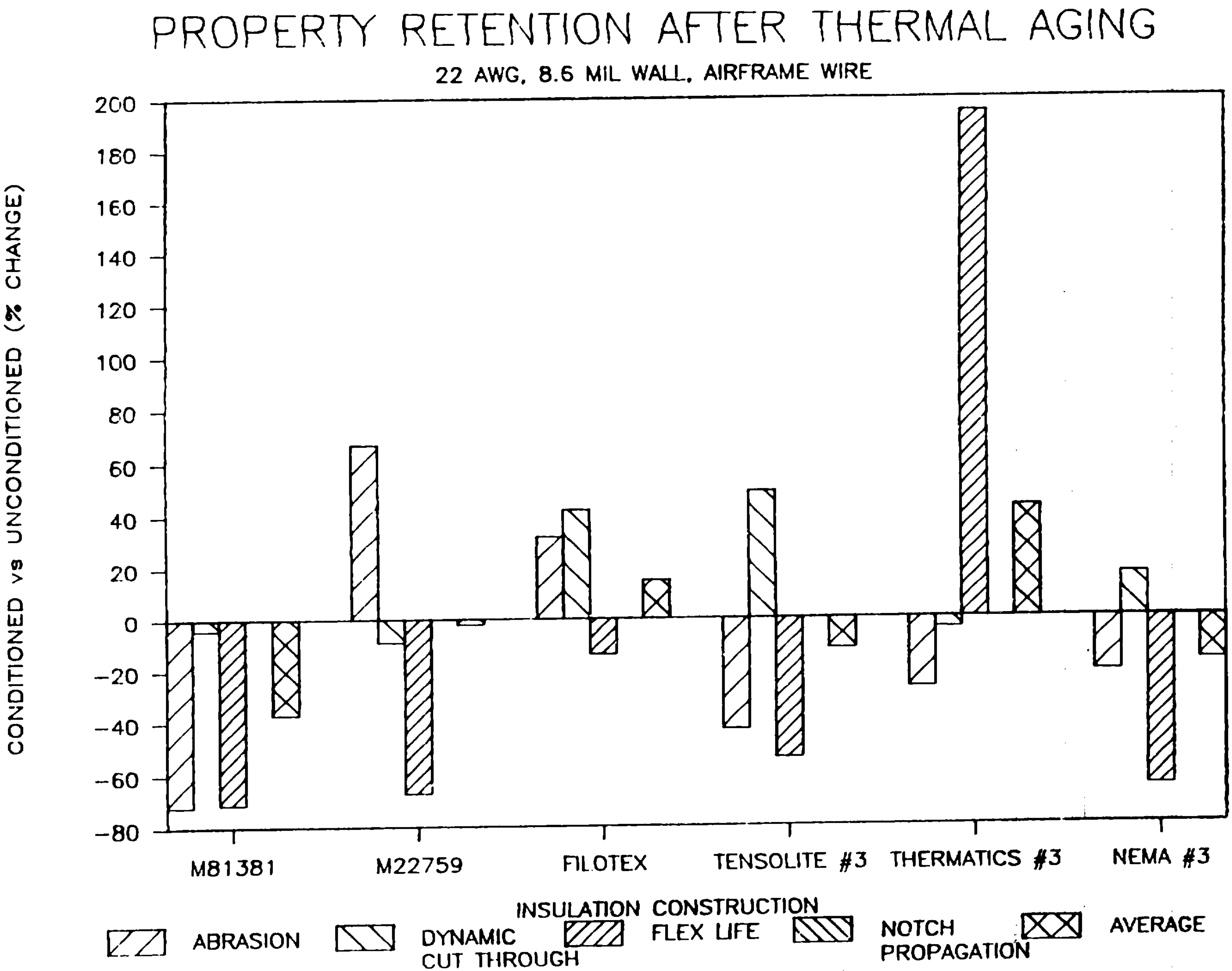


FIGURE 5.107 - PROPERTY RETENTION AFTER THERMAL AGING, 22AWG, 8.6 MIL WALL, AIRFRAME WIRE

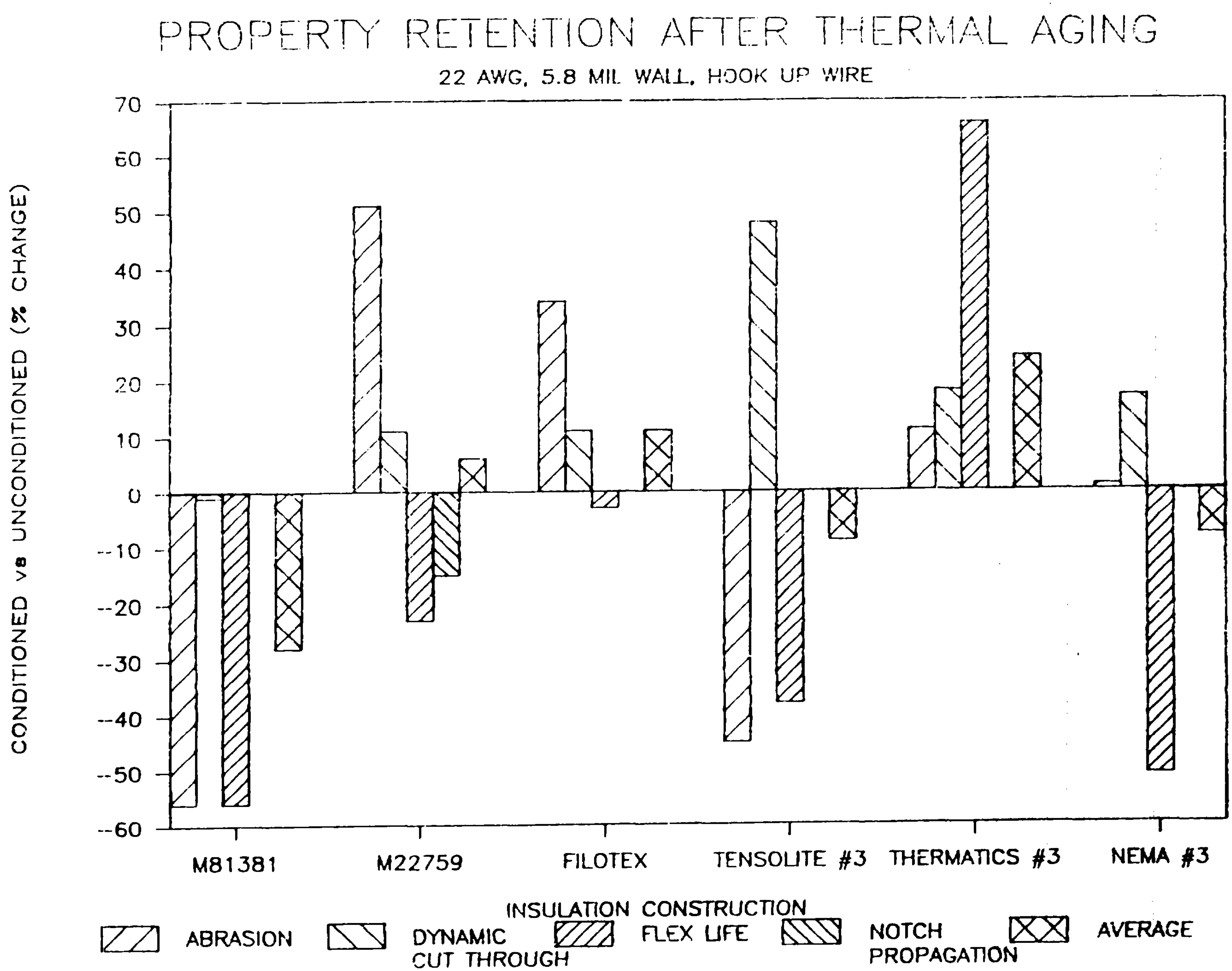


FIGURE 5.108 - PROPERTY RETENTION AFTER THERMAL AGING, 22AWG, 5.8 MIL WALL, HOOK UP WIRE

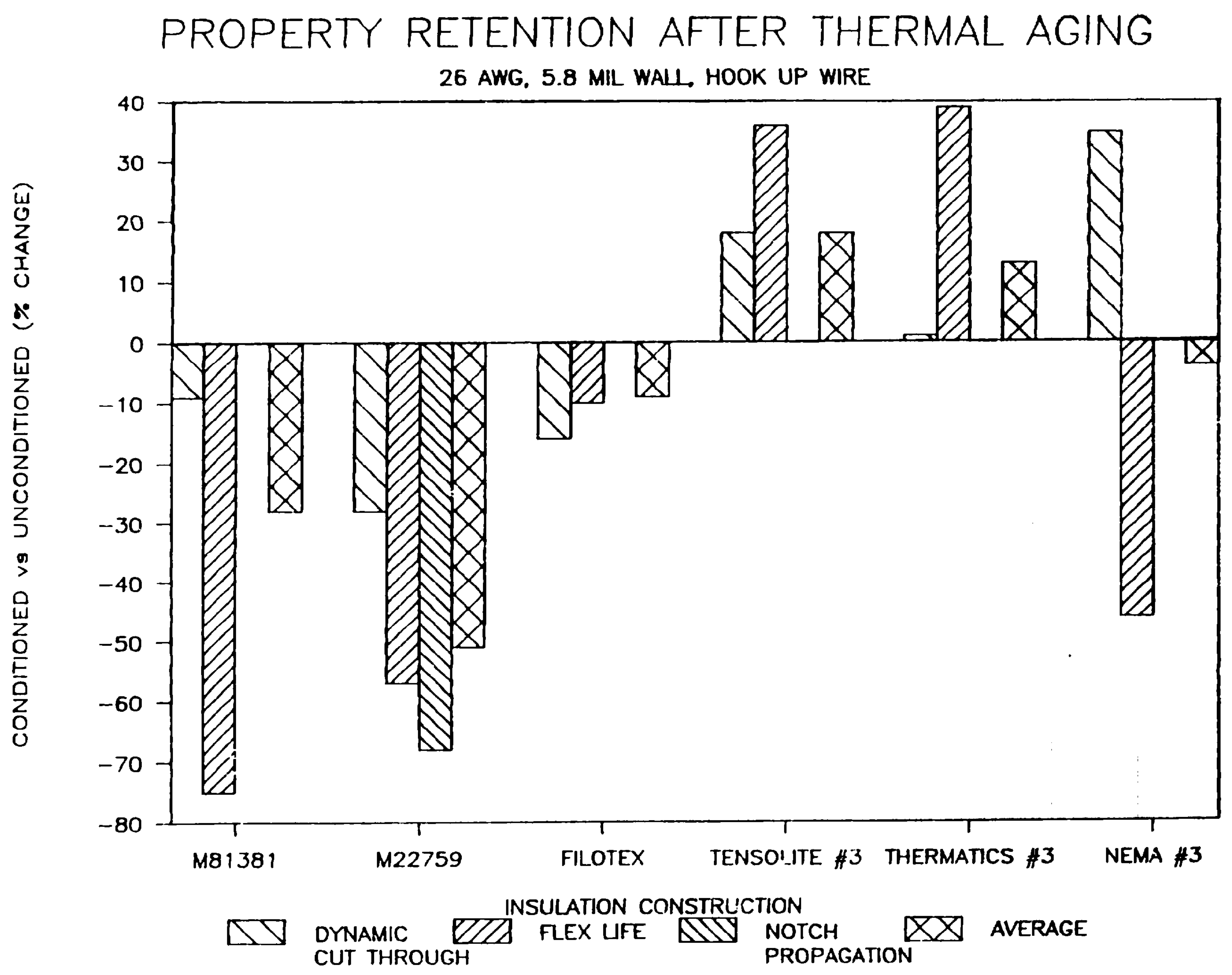


FIGURE 5.109 - PROPERTY RETENTION AFTER THERMAL AGING, 26AWG, 5.8 MIL WALL, HOOK UP WIRE

REFERENCES

TR-2333 dated 9 December 1982

Naval Avionics Center (NAC) Publication, Comparative Testing of Aircraft Electrical Wire, prepared by M.A. Sargent and J.P. Brack, approved by R.R. Wesolowski.

MDC-B0482 dated 4 September 1987

McDonnell-Douglas Corporation (MDC) Report, Performance Comparison of M81381/9, M22759/19, M22759/33, and Non-Mil Spec Wire and Cable, prepared by E.A. Muegge, approved by L.A. Burkhardt and R.S. Soloman.

EXHIBIT A

Photographic Documentation on British Standards Institute (BSI) Dry Arc Propagation Tests and Wet Arc Propagation Tests

Inclusive pages: 1-23

EXHIBIT B

Proposed Military Specification Slant Sheets for Tensolite and Thermatics Constructions

Inclusive pages: 1-2, 1-4, 1-4, 1-4, 1-4, 1-4, 1-4, 1-4, 1-4

EXHIBIT A - PHOTOGRAPHIC DOCUMENTATION ON

BSI DRY ARC PROPAGATION TESTS AND WET ARC PROPAGATION TESTS

This exhibit contains photographs of the specimens tested under the BSI Dry Arc Propagation Test and the Wet Arc Propagation Test.

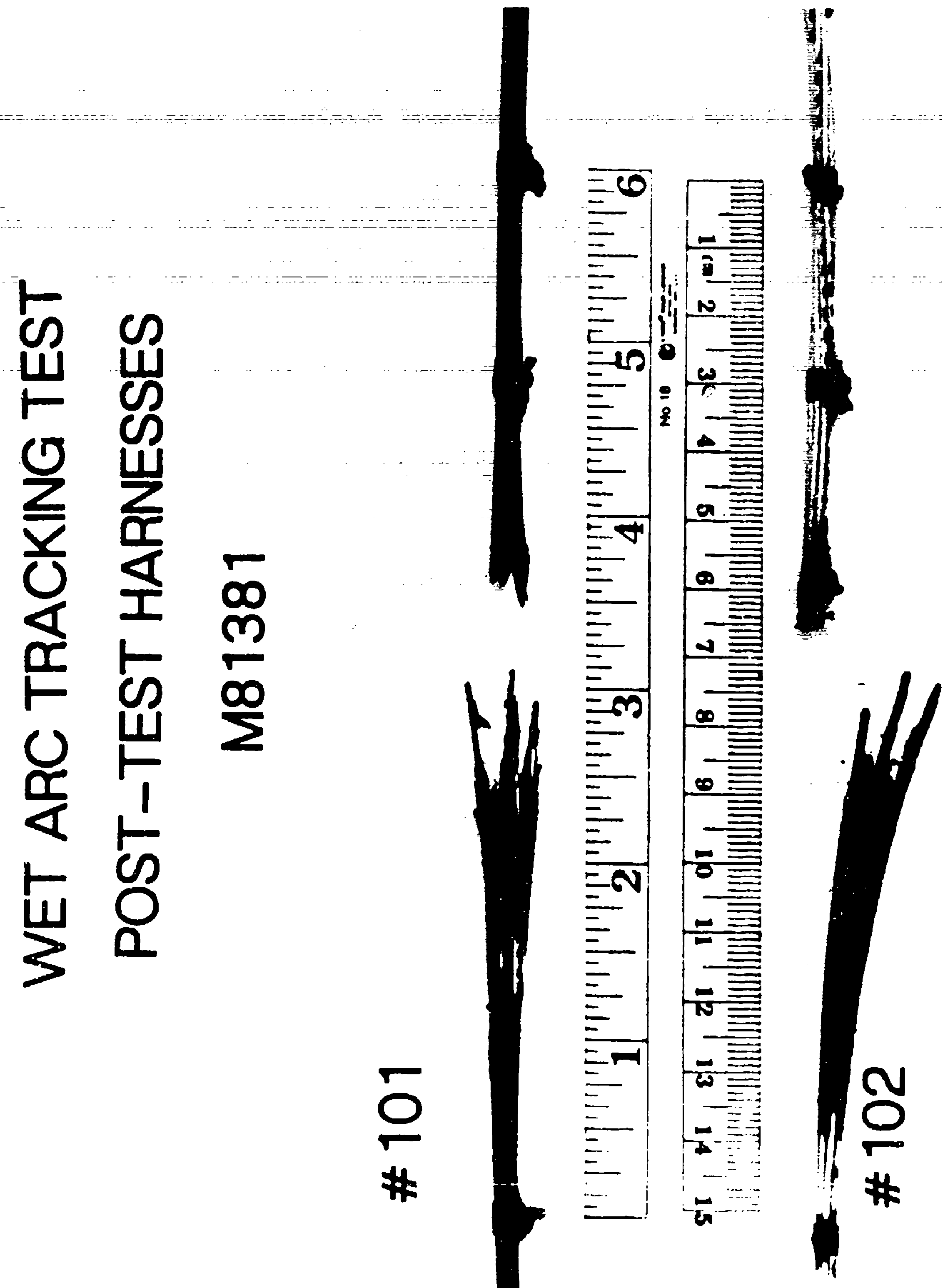


FIGURE 14.1 - WET ARC TRACKING RESULTS - M81381

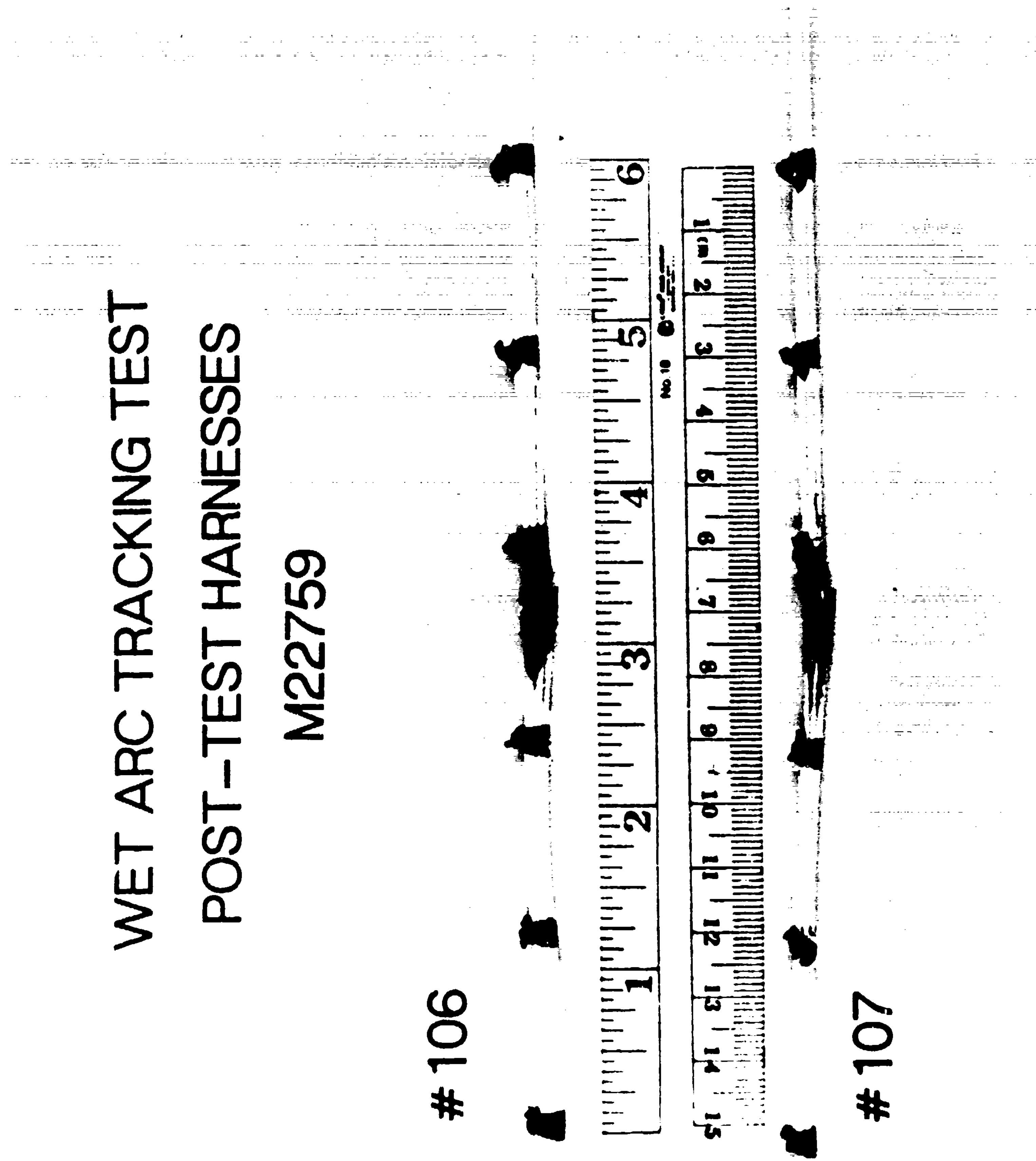


FIGURE 14.2 - WET ARC TRACKING RESULTS - M22759

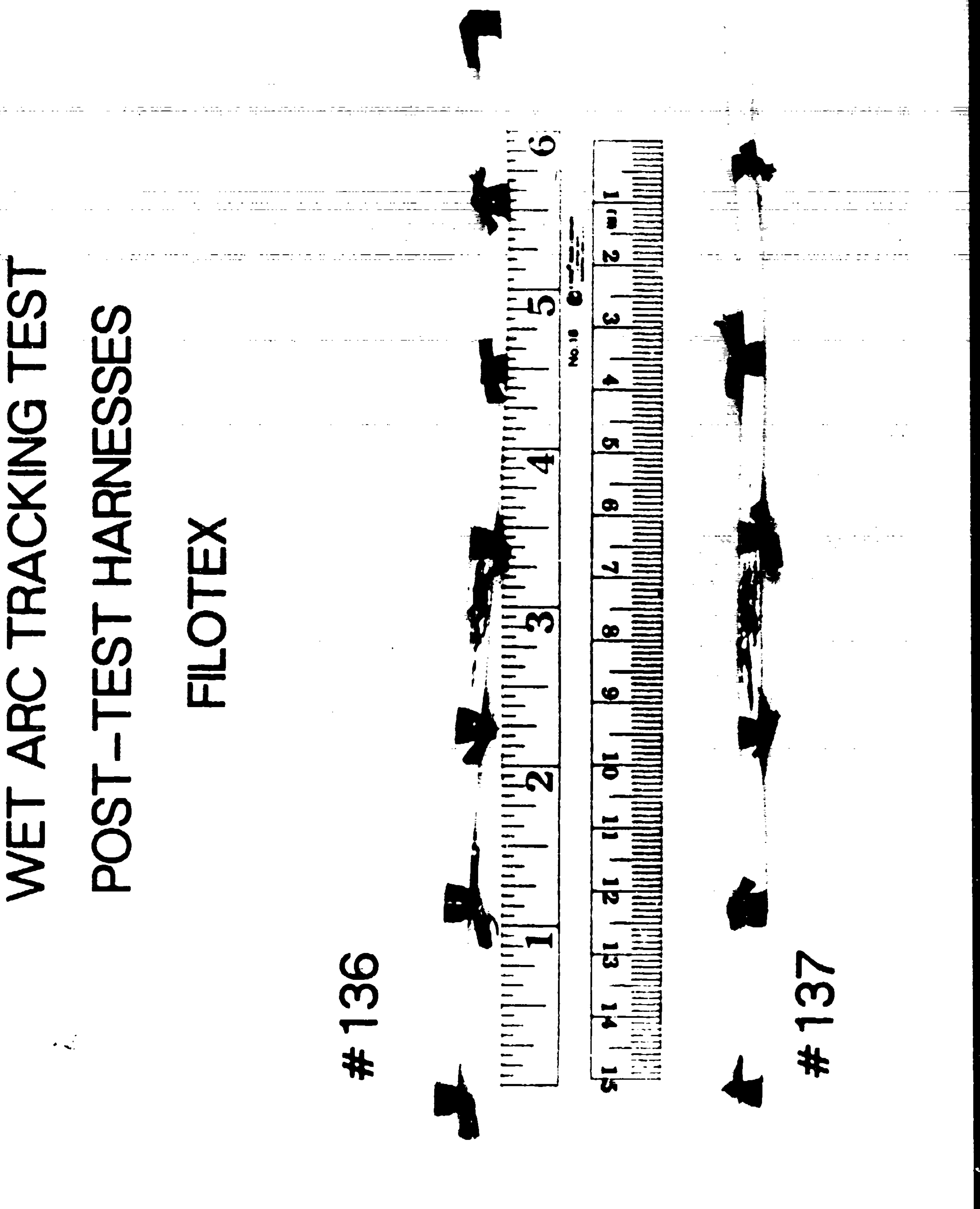


FIGURE 14.3 - WET ARC TRACKING RESULTS - FILOTEX

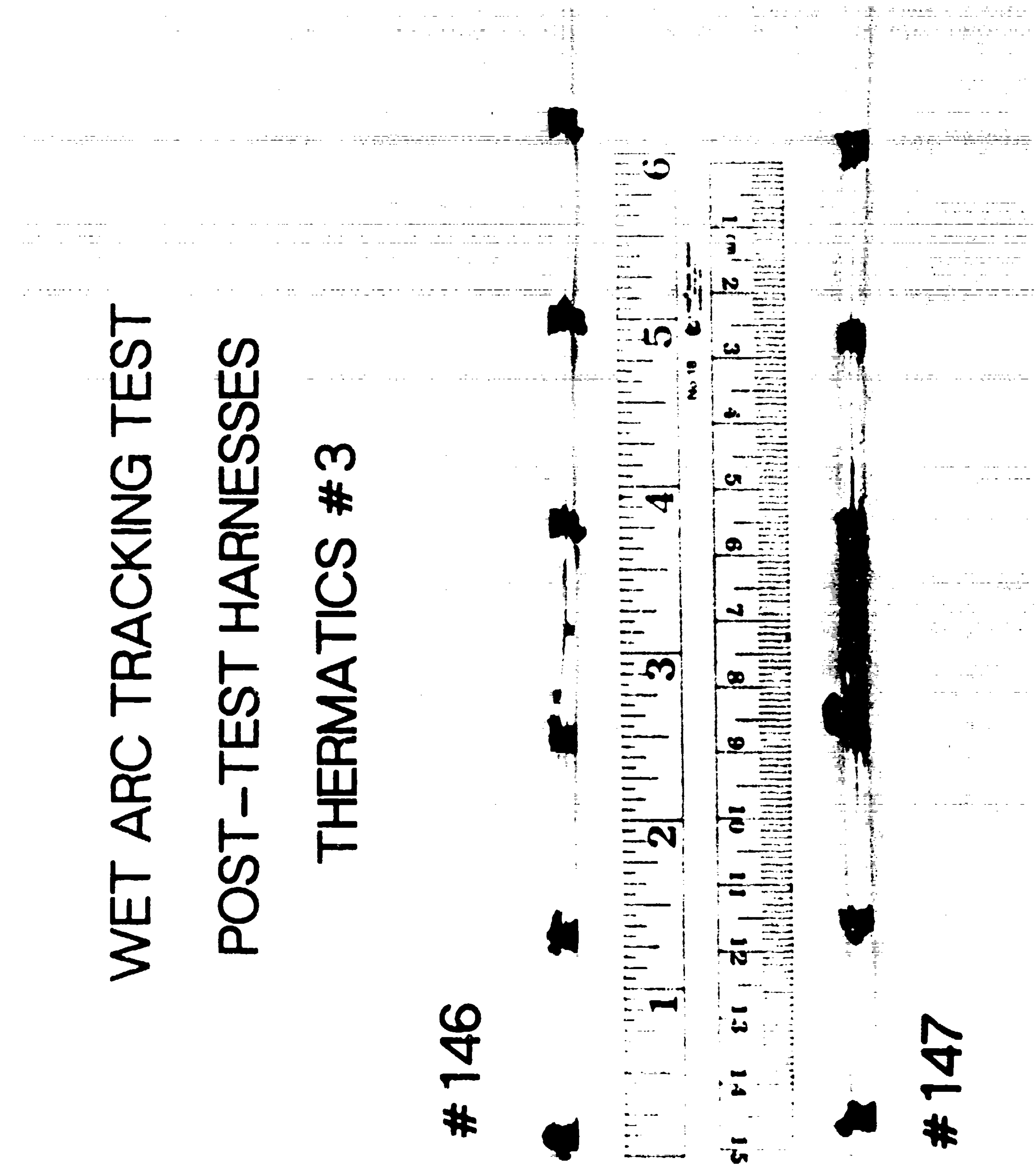


FIGURE 14.4 - WET ARC TRACKING RESULTS - THERMATICS #3

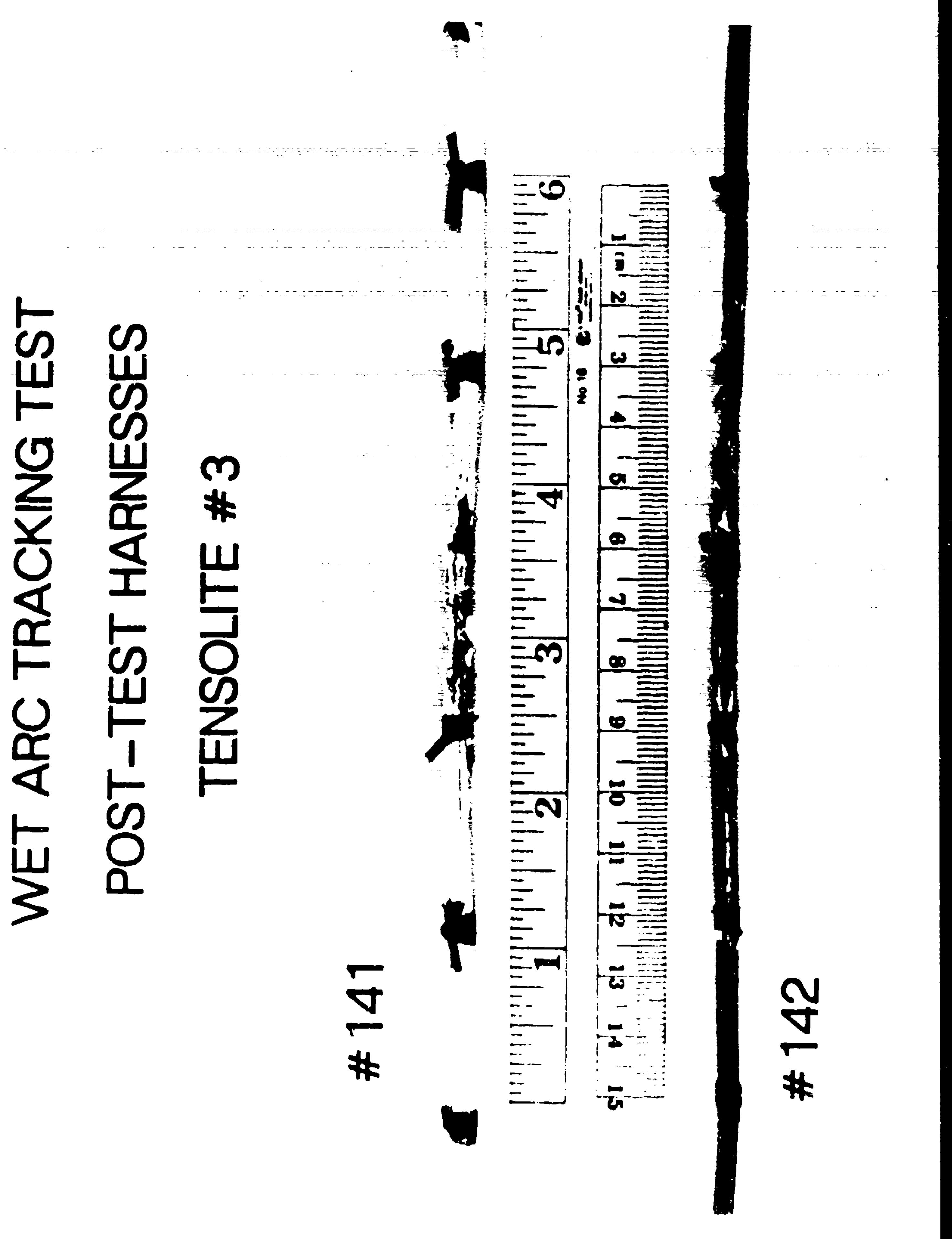


FIGURE 14.5 - WET ARC TRACKING RESULTS - TENSOLITE #3

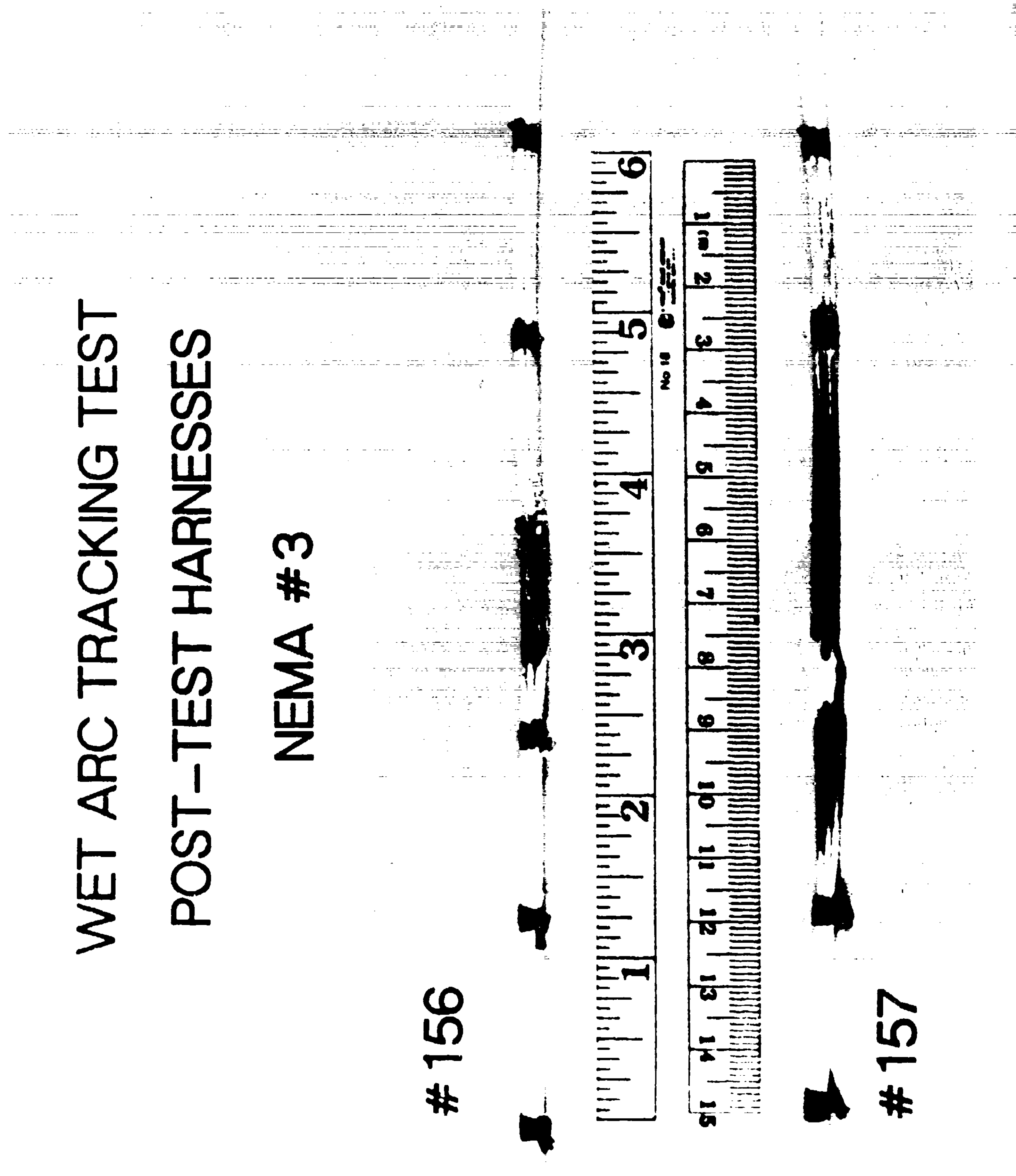


FIGURE 14.6 - WET ARC TRACKING RESULTS - NEMA #3

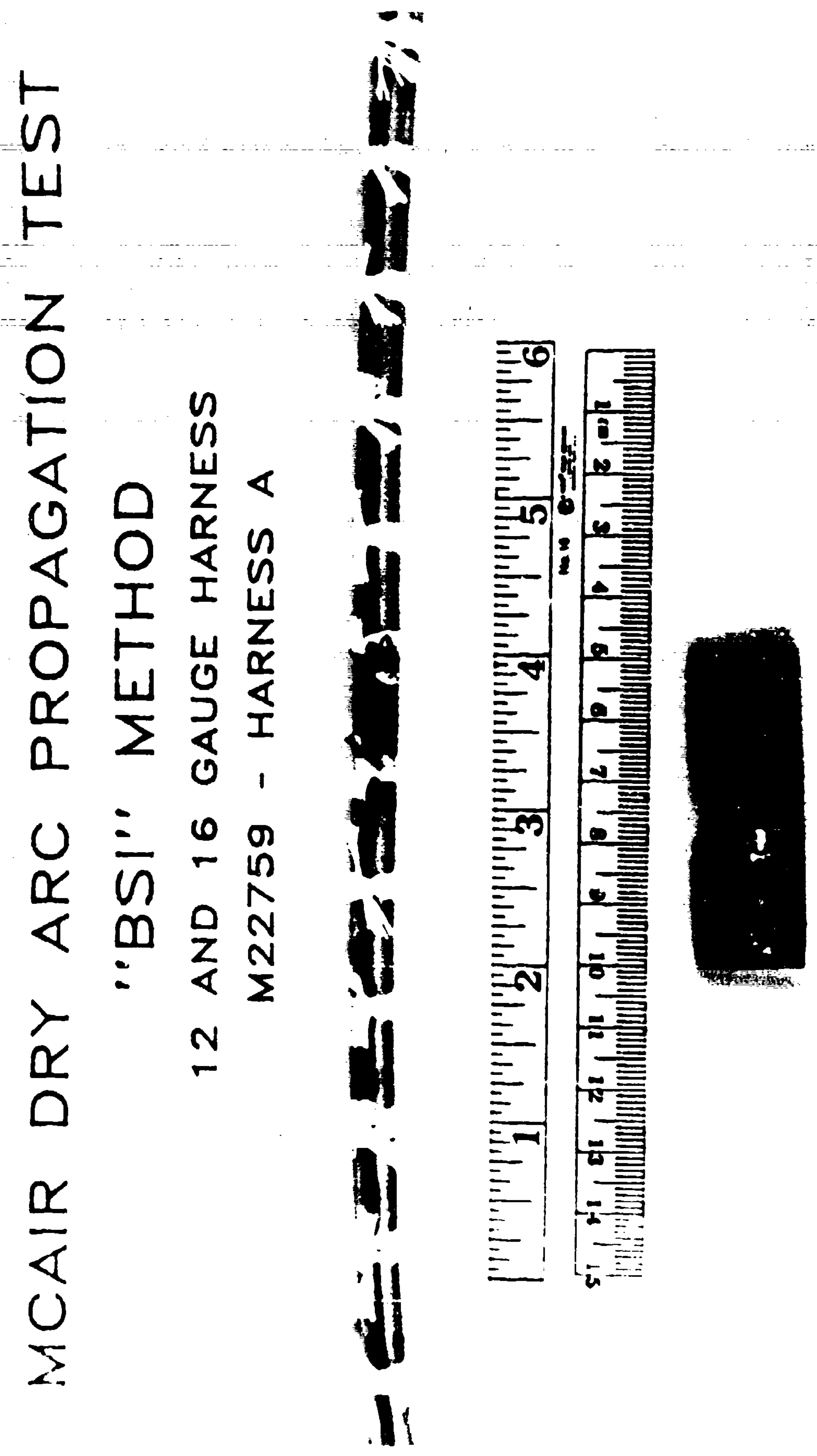


FIGURE 14.7 - "BSI" DRY ARC PROPAGATION TEST RESULTS - M22759 - HARNESS A

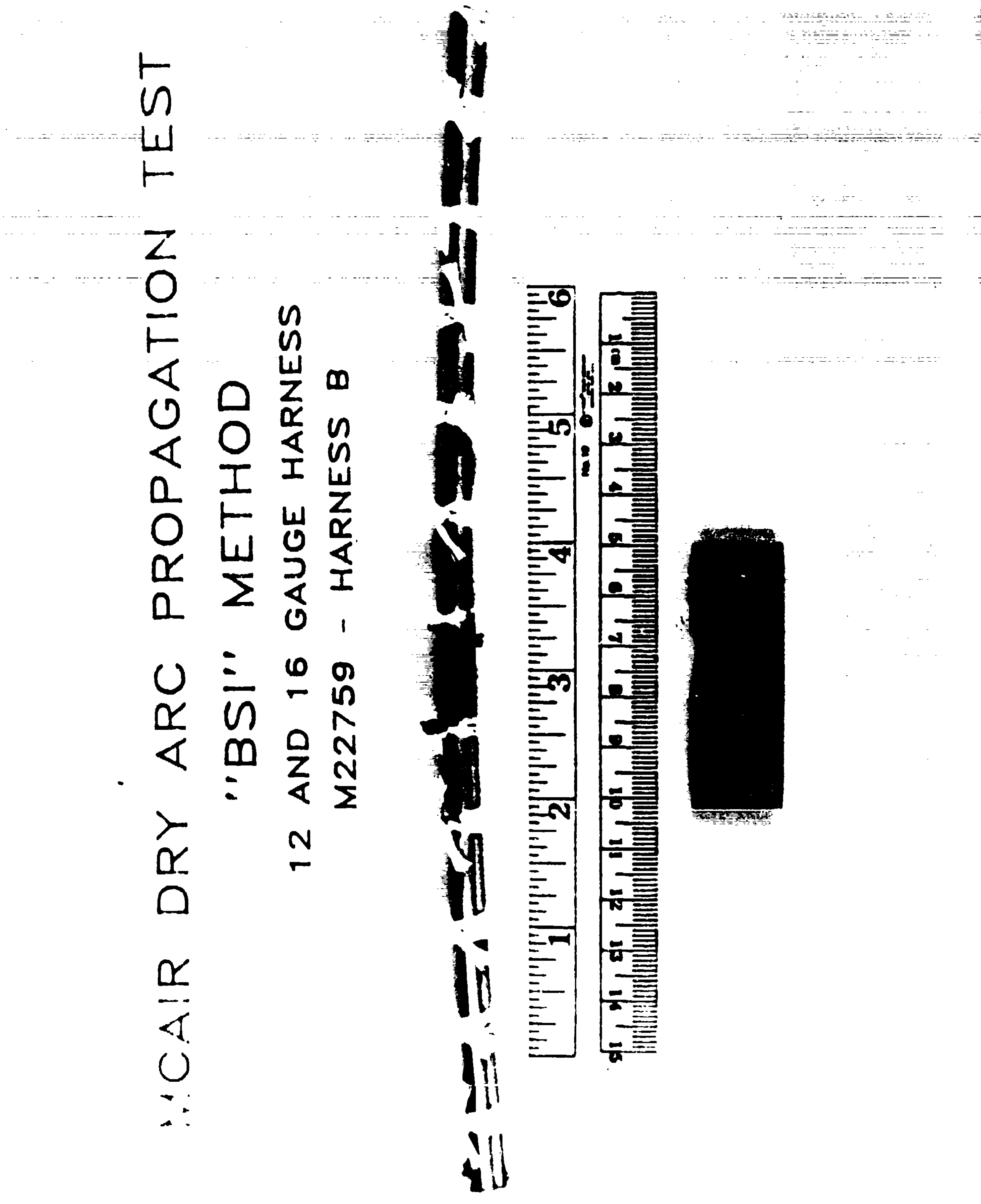


FIGURE 14.8 - "BSI" DRY ARC PROPAGATION TEST
RESULTS - M22759 - HARNESS B

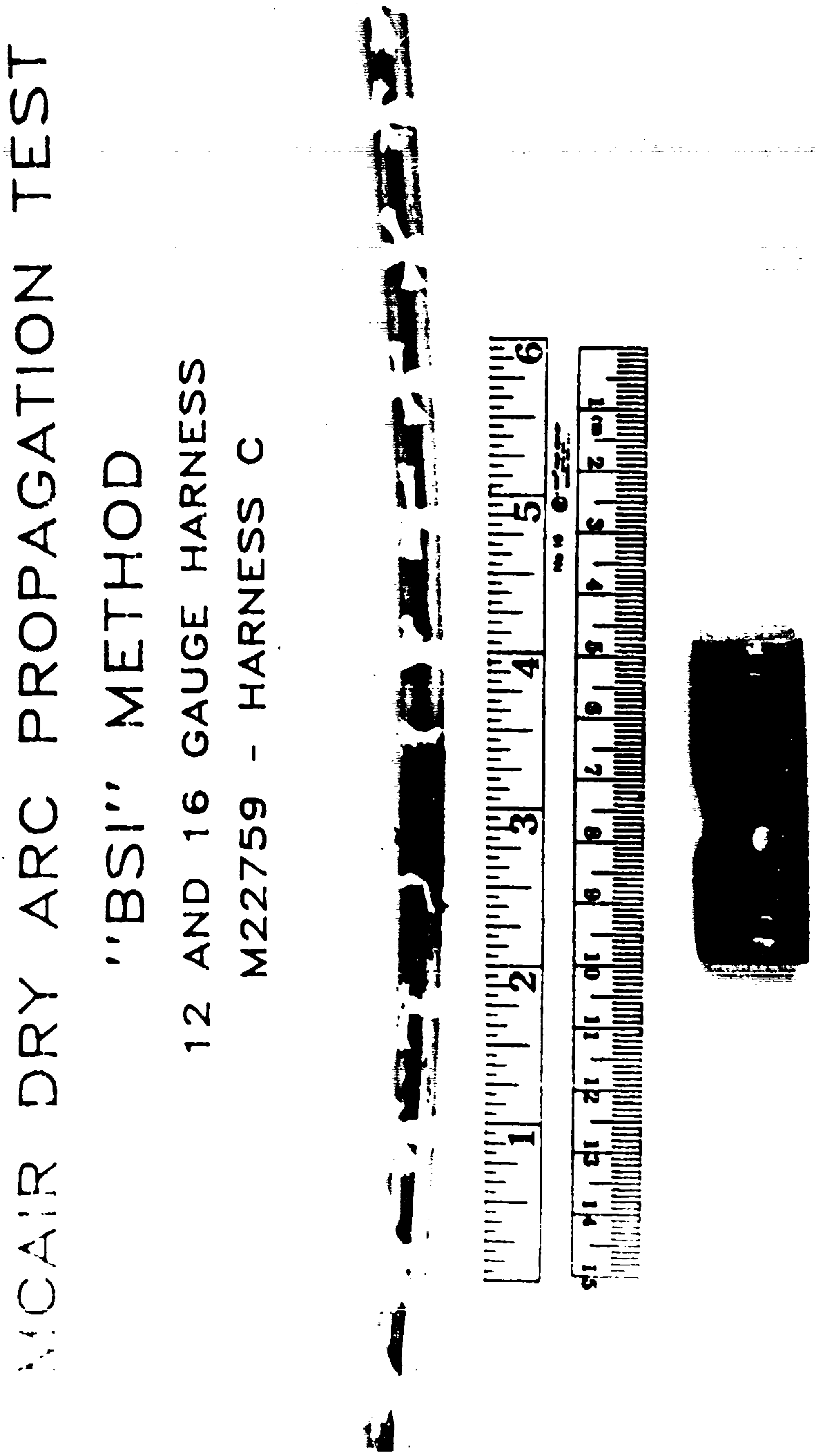


FIGURE 14.9 - "BSI" DRY ARC PROPAGATION TEST
RESULTS - M22759 - HARNESS C

MCAIR DRY ARC PROPAGATION TEST

"BSI" METHOD

12 AND 16 GAUGE HARNESS

TENSOLITE - HARNESS A

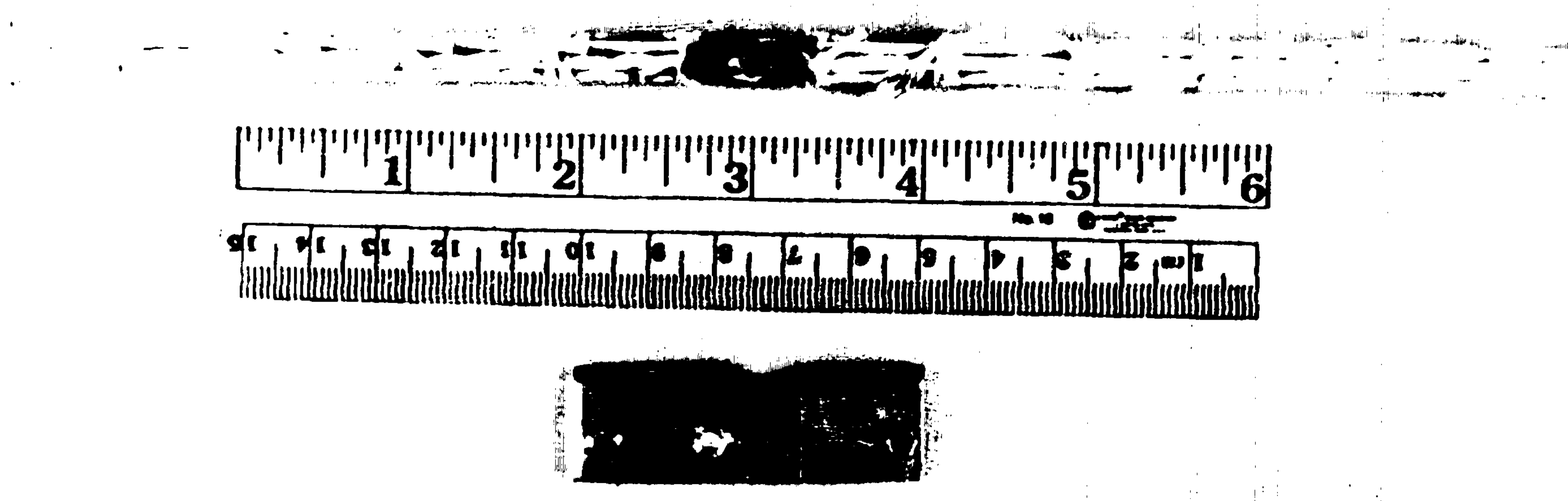


FIGURE 14.16 - "BSI" DRY ARC PROPAGATION TEST
RESULTS - TENSOLITE - HARNESS A

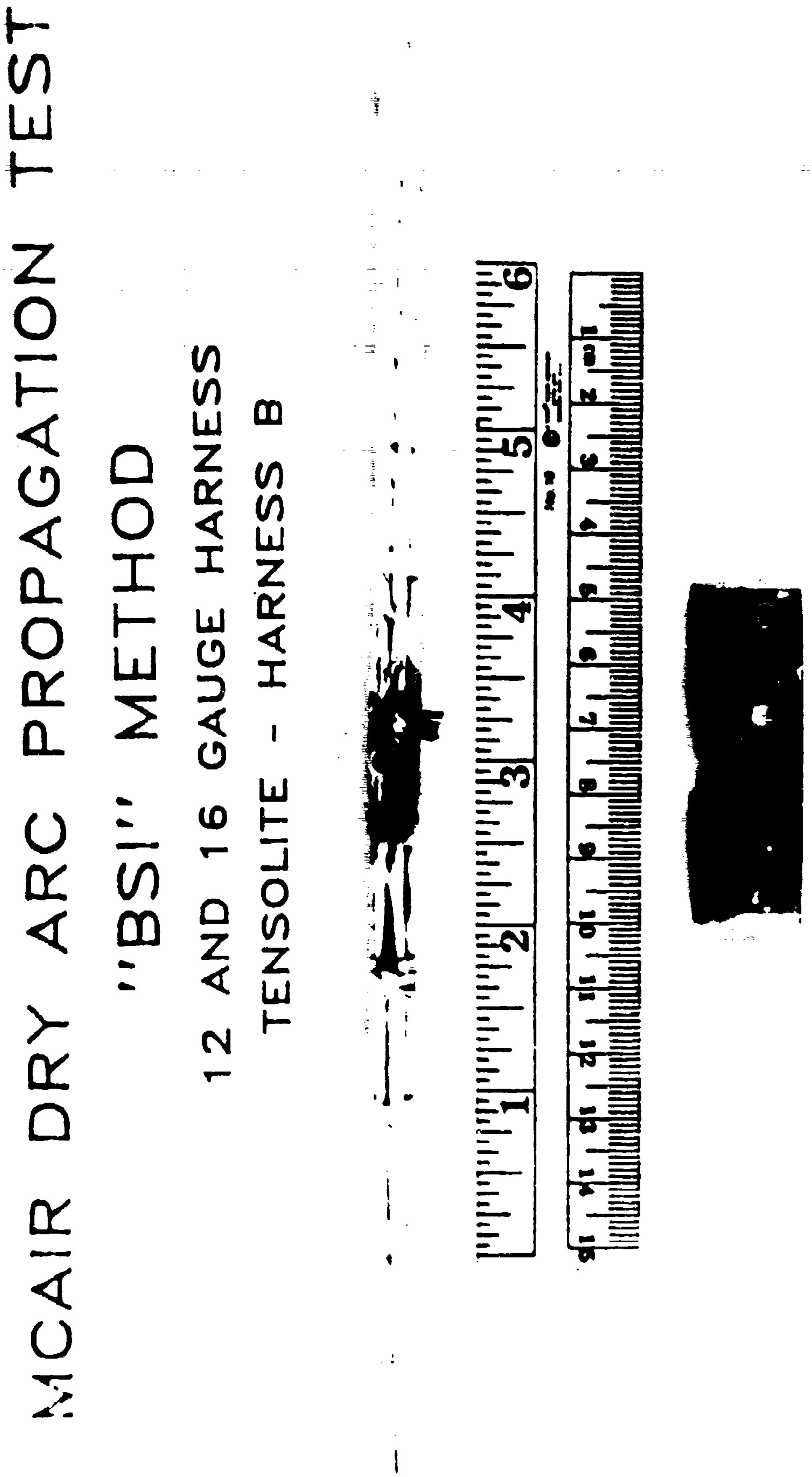


FIGURE 14.11 - "BSI" DRY ARC PROPAGATION TEST RESULTS - TENSOLITE - HARNESS B

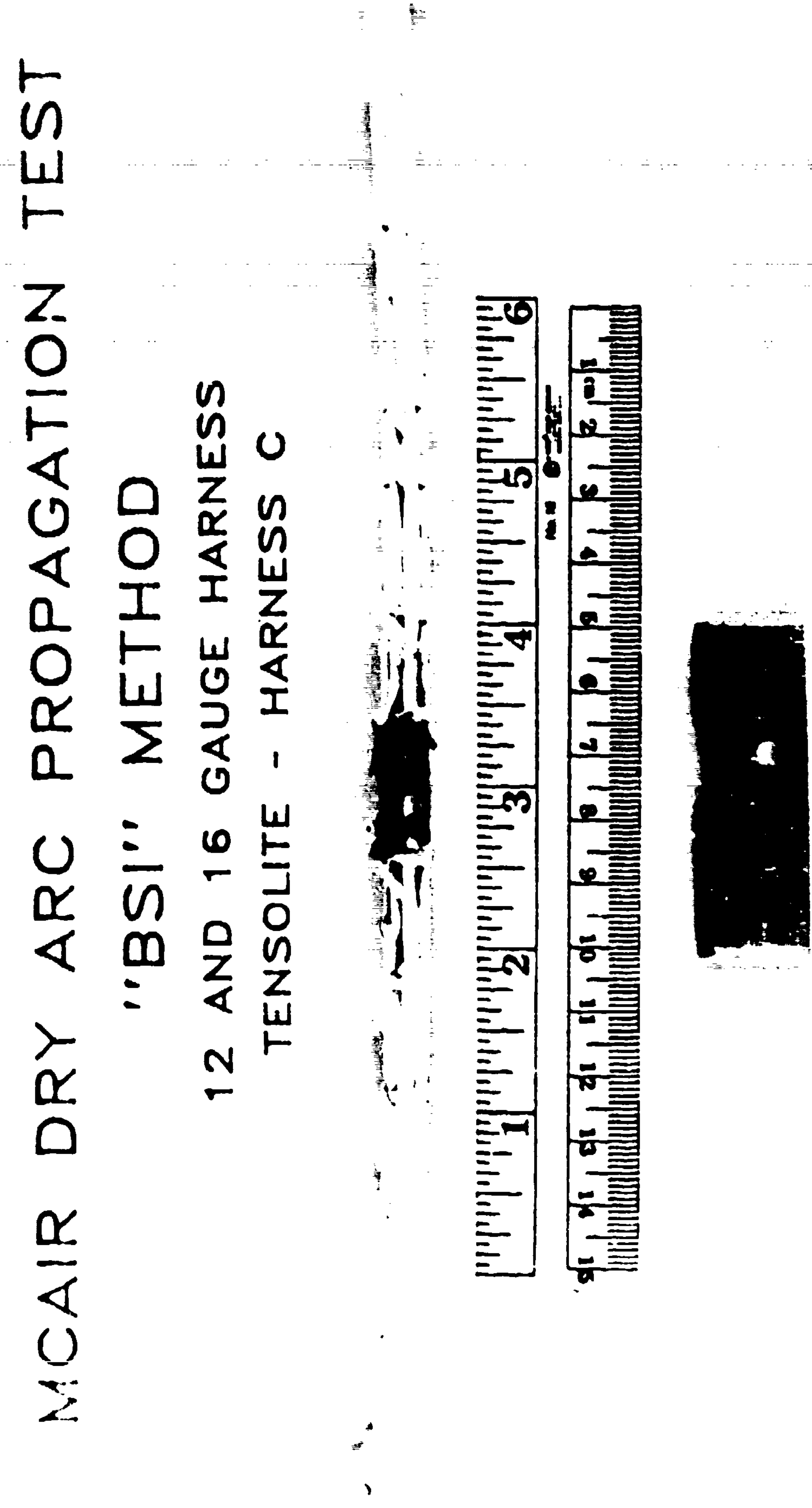


FIGURE 14.12 - "BSI" DRY ARC PROPAGATION TEST RESULTS - TENSOLITE - HARNESS C

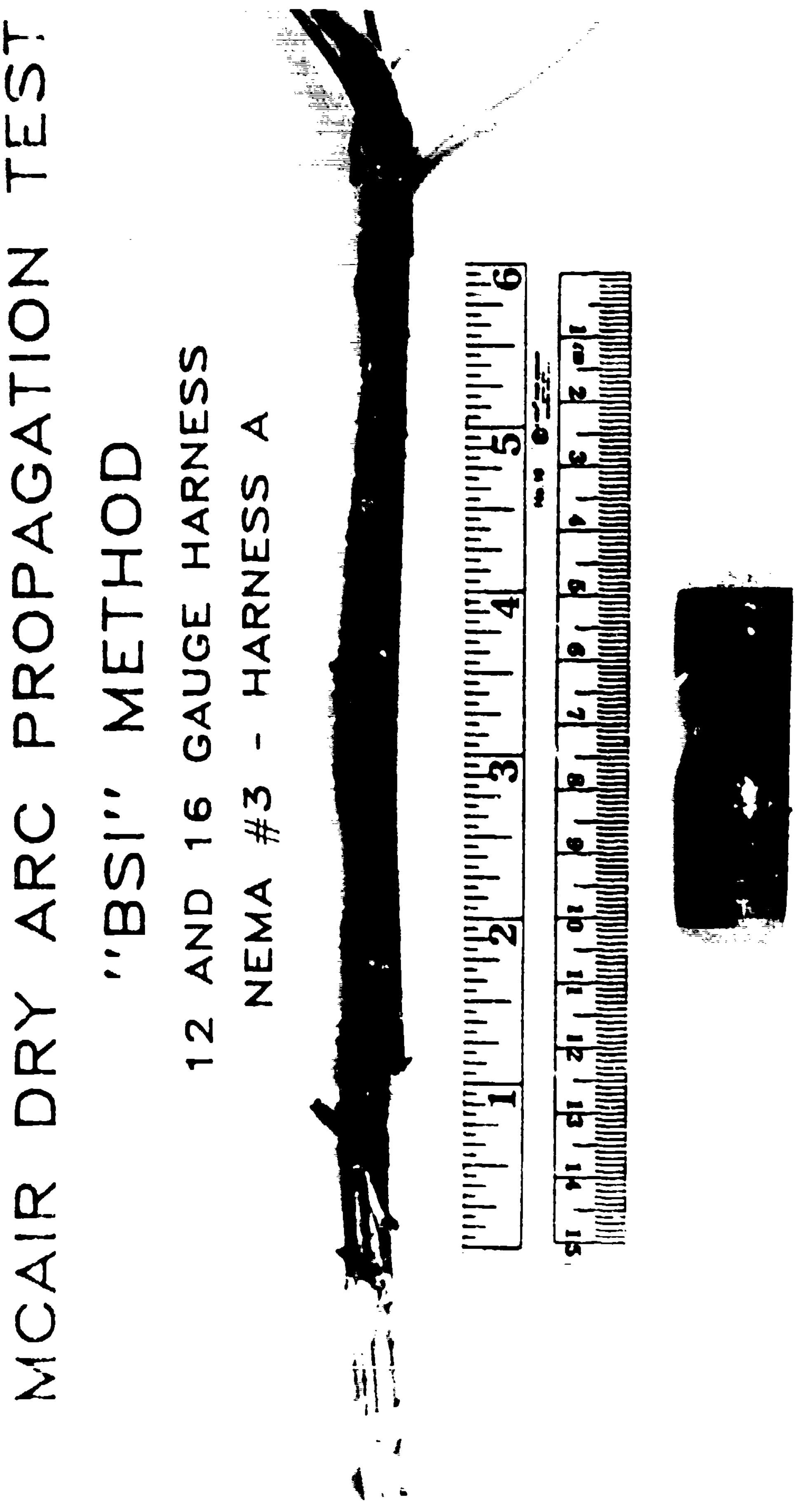


FIGURE 14.13 - "BSI" DRY ARC PROPAGATION TEST RESULTS - NEMA #3 - HARNESS A

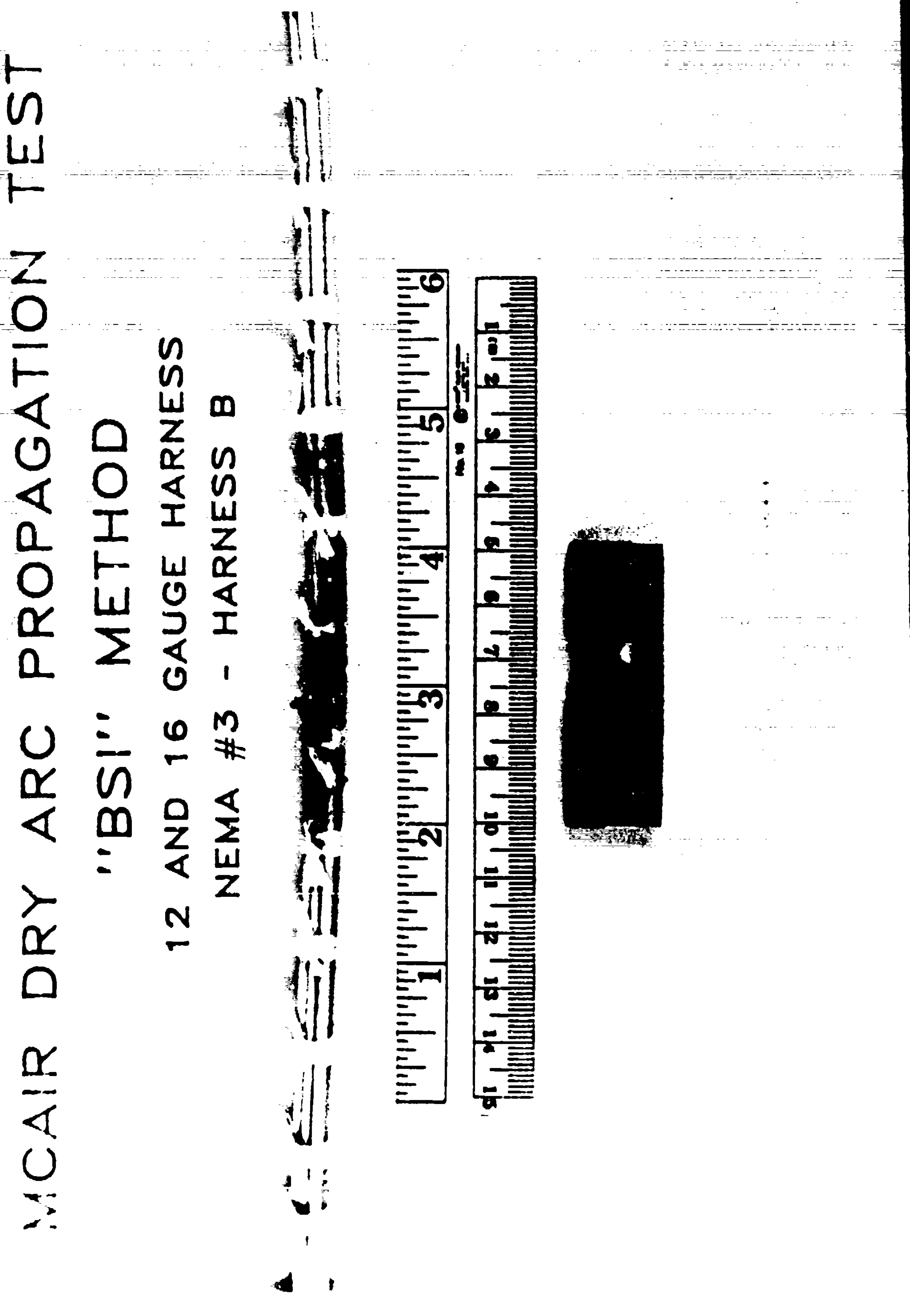


FIGURE 14.14 - "BSI" DRY ARC PROPAGATION TEST RESULTS - NEMA #3 - HARNESS B

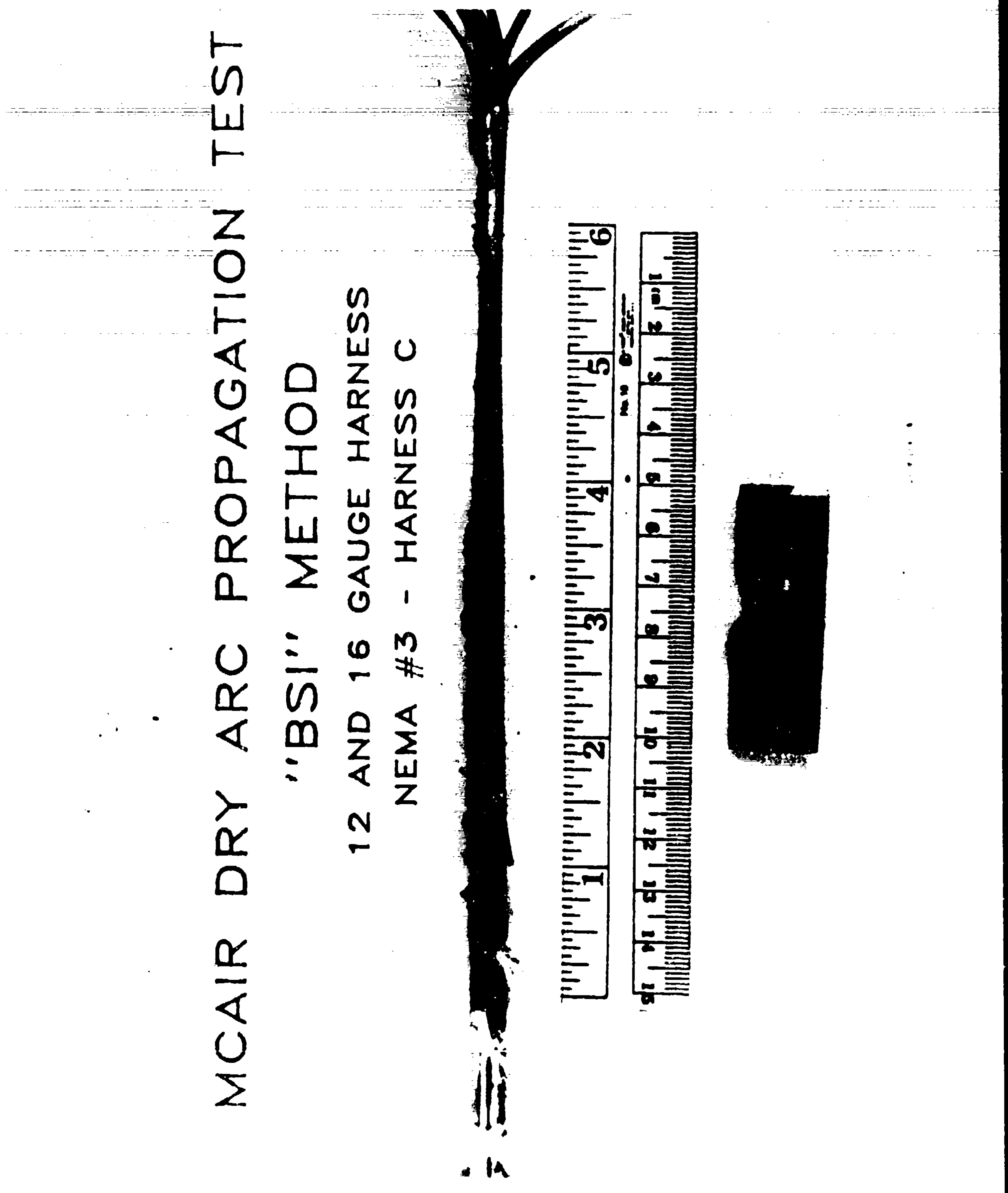


FIGURE 14.15 - "BSI" DRY ARC PROPAGATION TEST RESULTS - NEMA #3 - HARNESS C

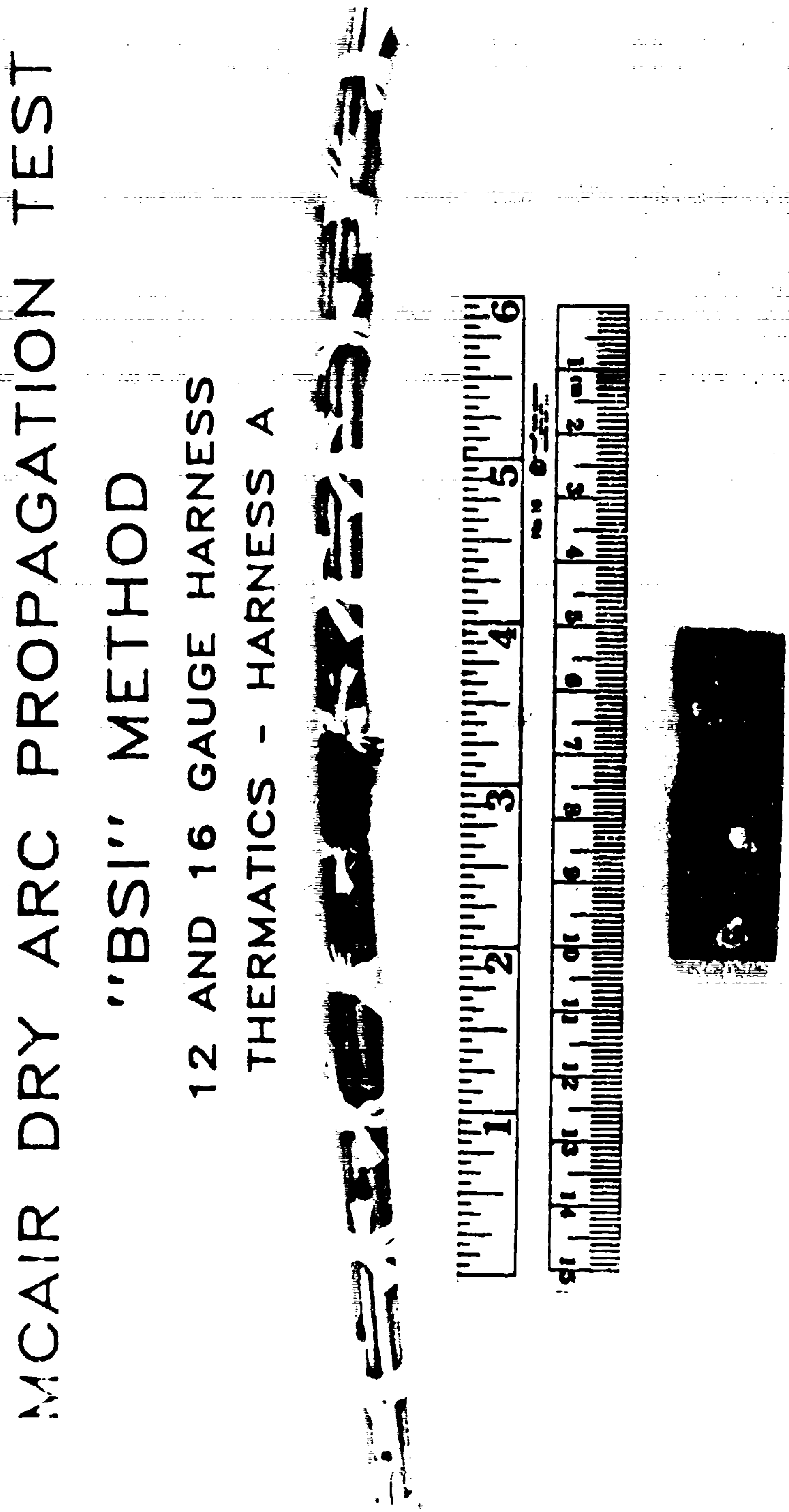


FIGURE 14.16 - "BSI" DRY ARC PROPAGATION TEST RESULTS - THERMATICS - HARNESS A

MCAIR DRY ARC PROPAGATION TEST

"BSI" METHOD

12 AND 16 GAUGE HARNESS

THERMATICS - HARNESS B

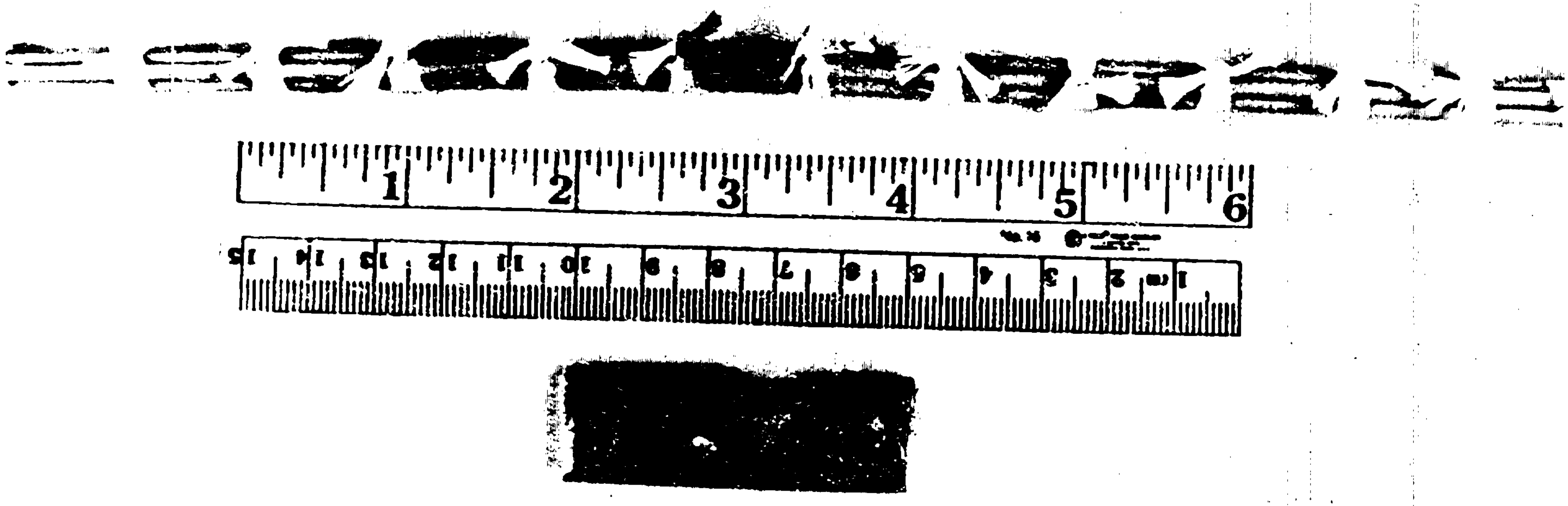


FIGURE 14.17 - "BSI" DRY ARC PROPAGATION TEST RESULTS - THERMATICS - HARNESS B

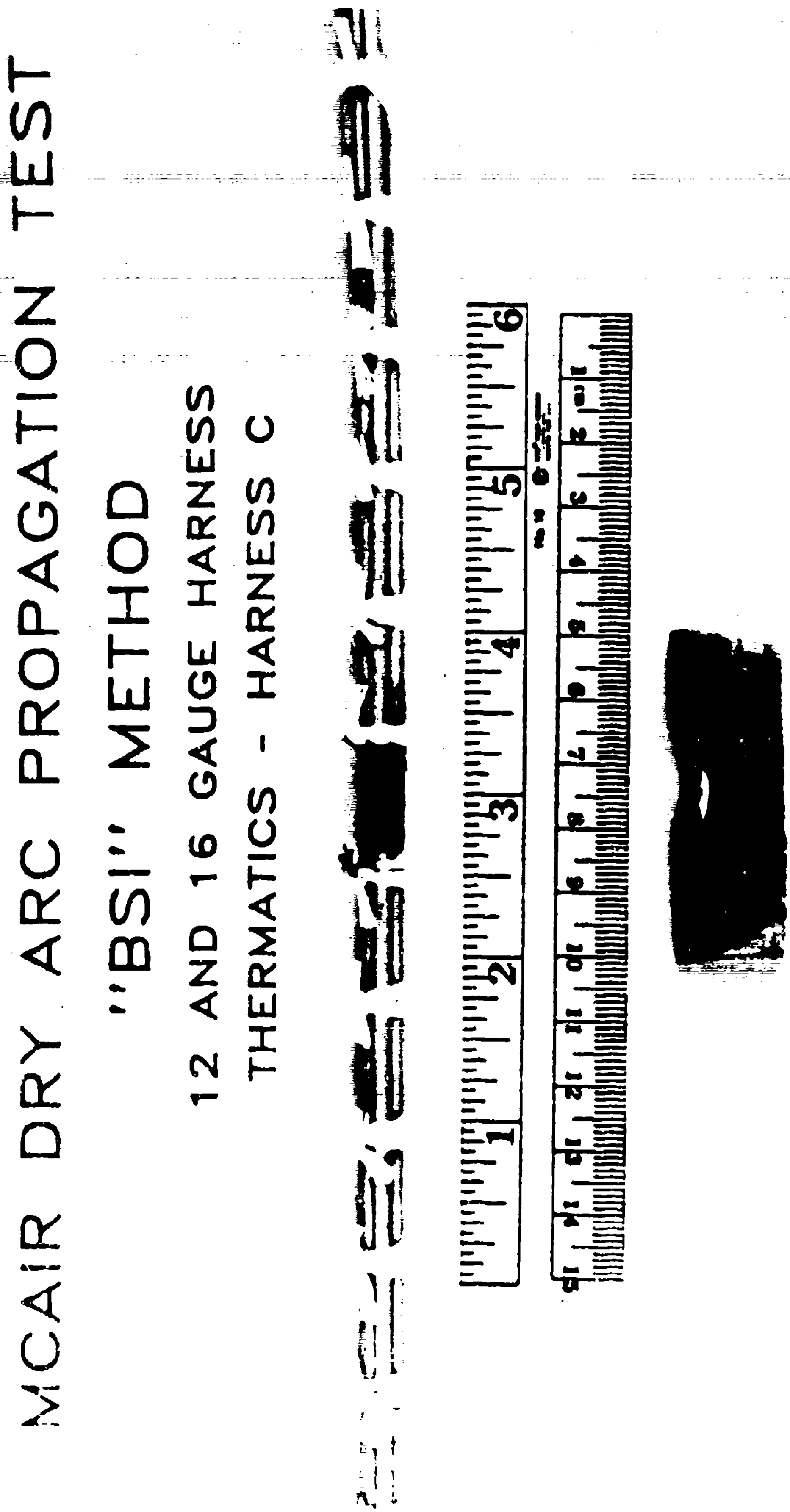


FIGURE 16.18 - "BSI" DRY ARC PROPAGATION TEST RESULTS - THERMATICS - HARNESS C

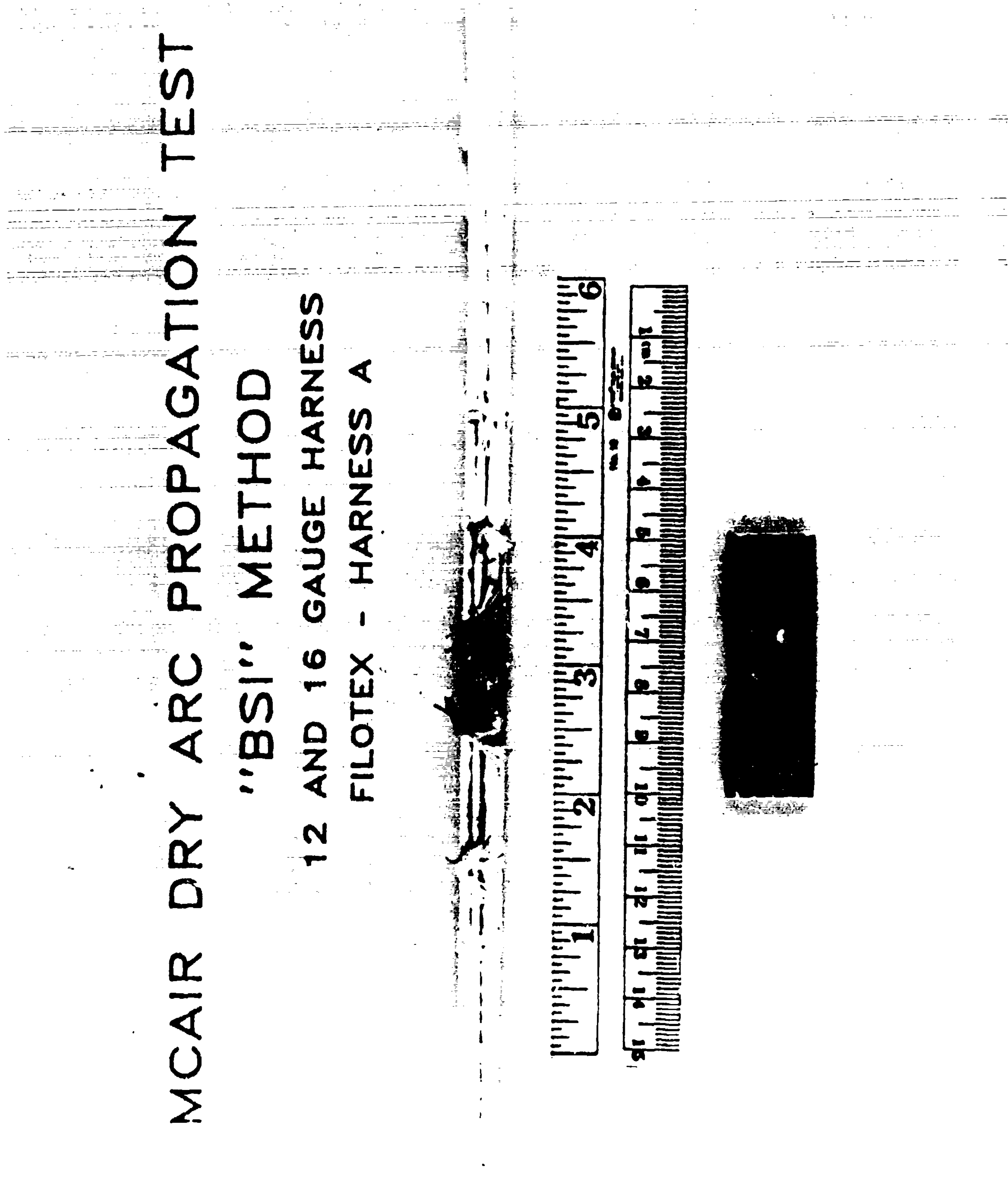


FIGURE 14.19 - "BSI" DRY ARC PROPAGATION TEST RESULTS - FILOTEX - HARNESS A

MCAIR DRY ARC PROPAGATION TEST

"BSI" METHOD

12 AND 16 GAUGE HARNESS

FILOTEX - HARNESS B

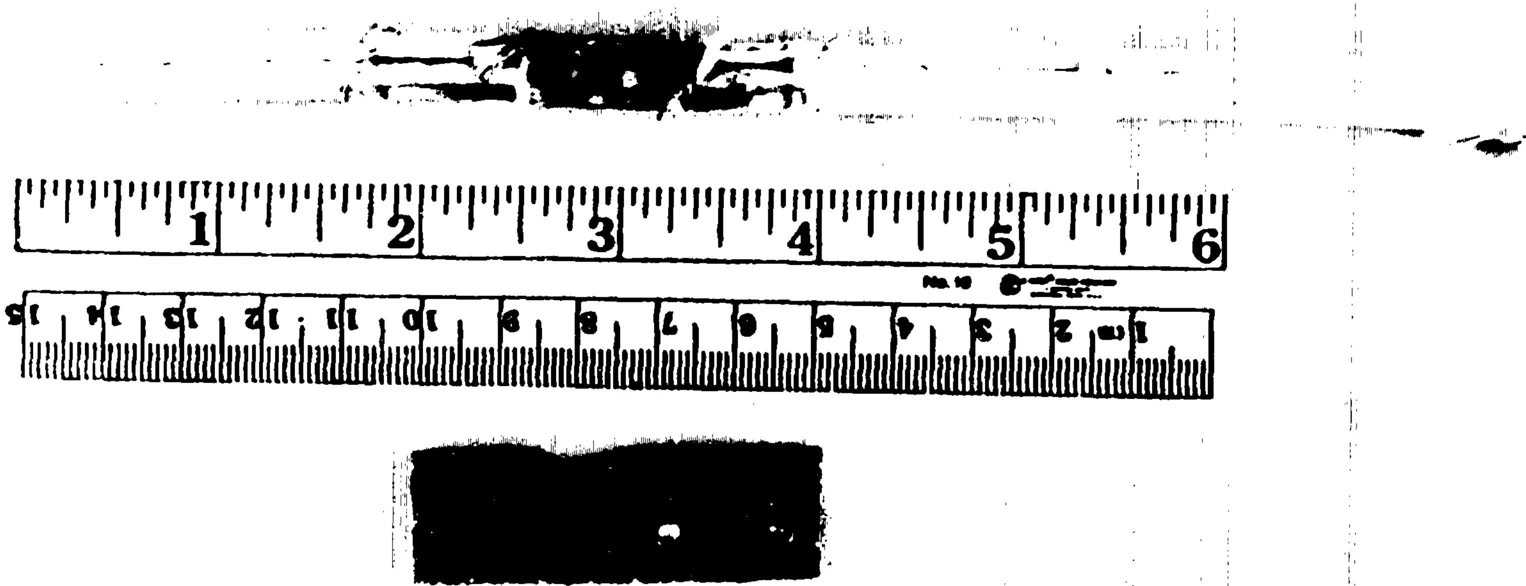


FIGURE 14.20 - "BSI" DRY ARC PROPAGATION TEST RESULTS - FILOTEX - HARNESS B

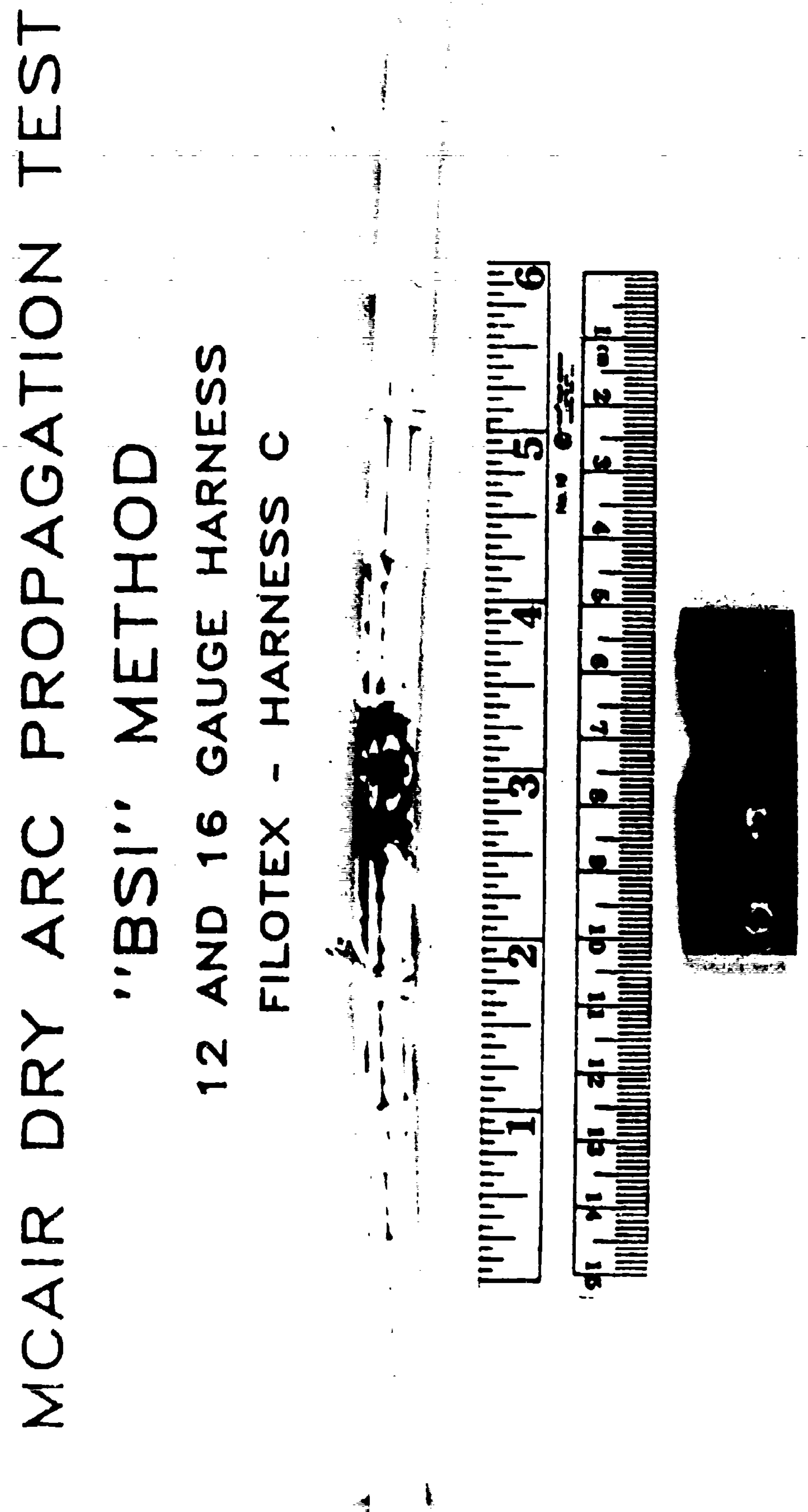


FIGURE 14.21 - "BSI" ARC PROPAGATION TEST
RESULTS - FILOTEX - HARNESS C

EXHIBIT B - PROPOSED MILITARY SPECIFICATION SLANT SHEETS FOR TENSOLITE AND THERMATICS CONSTRUCTIONS

This Exhibit contains proposed military specification sheets for the Thermatics fluorocarbon/polyimide/fluorocarbon construction and the Tensolite polyimide/fluorocarbon constructions. The Thermatics construction came the closest to meeting all the program requirements (multiple sources, insulation material availability, silver plated conductor, CS 95 alloy in 26 awg and within M81381 diameters and weights). The Thermatics construction finished third in overall candidate performance. The Tensolite construction finished second in the overall candidate performance but when the original draft specification sheets were submitted by Tensolite, the diameters and weights exceeded M81381 requirements. Subsequent discussion with Tensolite indicated they were reluctant to provide diameters and weights within M81381 because of concerns with arc propagation in wet and dry arc tracking tests. As a result, the Tensolite KT construction was remanufactured within diameters and weights compatible with M81381 and arrangements made to retest the KT in wet and dry arc propagation. Successful completion of these tests will result in the US Air Force recommending the KT construction along with the TKT construction and both specification sheets being offered for incorporation into M22759 as slant sheets.

Both proposed slant sheet configurations include the requirements for specific optical smoke density after 20 minutes exposure in the NBS Smoke Chamber. The proposed specification value of 5 is a reflection of the performance of these constructions in test and does not reflect a minimum requirement in the cockpit. Investigation is being conducted with the MCAIR Human Factors engineers to se if any history or data exists that could be considered meaningful in establishing a minimum smoke density relevant to successful operation in the cockpit. If such information is available, a minimum performance number would be preferred over the actual value measured in test as it would be more reflective of real world operating conditions.

Each construction has four slant sheets. The four slant sheets are: A. Light weight (LW) silver plated alloy (A); B. Light weight (LW) silver plated copper (C); C. Normal weight (NW) silver plated alloy (A); and D. Normal weight (NW) silver plated copper (C).

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC, PTFE/POLYIMIDE/PTFE, AND PTFE INSULATED LIGHTWEIGHT, SILVER COATED COPPER ALLOY CONDUCTOR, 200°C, 600 VOLTS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the wire described herein shall consist of this specification and the latest issue of MIL-W-22759

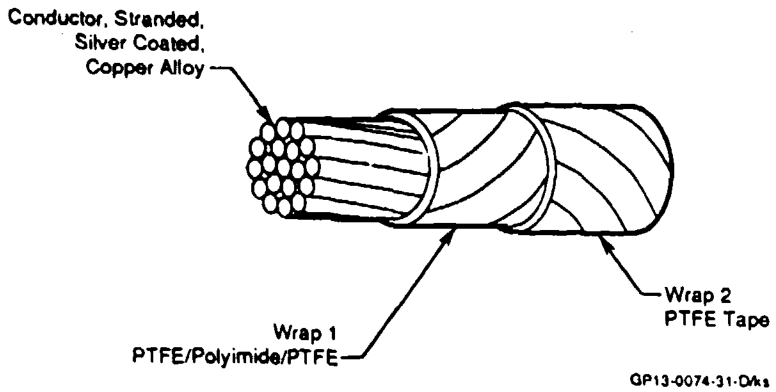


Figure 1. General Configuration

TABLE I. CONSTRUCTION DETAILS

Part No. 1/	Wire Size (AWG)	Conductor 2/			Finished Wire				Insulation Tapes	
		Stranding (Number of Strands x AWG Gauge of Strands)	Diameter of Stranded Conductor (in.) Min	Diameter of Stranded Conductor (in.) Max	Resistance at 20°C (68°F) (ohms/1,000 ft) (Max)	Diameter (in.) Min	Diameter (in.) Max	Weight (lb/1,000 ft) (Max)	Wrap 1	Wrap 2
M22759/ -26-*	26	19 x 38	0.018	0.019	61.3	0.030	0.033	1.3	3/ 50% Min Overlap	4/ 50% Min Overlap
M22759/ -24-*	24	19 x 36	0.023	0.024	28.4	0.034	0.038	2.0		
M22759/ -22-*	22	19 x 34	0.029	0.030	17.5	0.039	0.043	2.9		
M22759/ -20-*	20	19 x 32	0.037	0.038	10.7	0.047	0.051	4.4		

GP13-0074-32-D/ks

1/ Part number: The asterisks in the part number column, Tables I and II, shall be replaced by color code designators in accordance with MIL-STD-681. Examples: Size 20, white - M22759/ -20-9; white with orange stripe - M22759/ -20-93. Printing of color code designator on surface of wire insulation is not required.

2/ Conductor code: 20/22/24 AWG: High strength, silver coated, copper alloy, PD-135; 26 AWG: High strength, silver coated, copper alloy, CS-95.

3/ Tape code: .00025" PTFE fluorocarbon resin/.001" polyimide film/.00025" PTFE fluorocarbon resin.

4/ Tape code: .0015" PTFE.

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

FSC 6145

TABLE II. TEST MANDREL AND TEST LOAD REQUIREMENTS

Wire Size (AWG)	Test Mandrel Diameter 1/ 2/ (in.)				Test Load 1/ (lb)		
	Life Cycle	Bend Test	Cold Bend	Wrap	Life Cycle	Bend Test	Cold Bend
26	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
24	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
22	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75
20	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75

GP13-0074-33-D/kas

TABLE III. MARKING AND COLOR DURABILITY TEST LOADS

Wire Size (AWG)	Test Load 1/ (grams)
26 2/	75
24 2/	75
22	100
20	100

GP13-0074-34-D/kas

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Marking is not applicable.

RATINGS:

Temperature rating: 200°C (392°F) maximum continuous conductor temperature.
Voltage rating: 600 volts (rms) at sea level.

ADDITIONAL REQUIREMENTS:

Acid resistance: No requirement.
Arc propagation: No propagation or tracking (qualification only).
Blocking: 230°C ± 3°C (446°F ± 5.4°F).
Color: In accordance with MIL-STD-104, class 1; white preferred. Conformity of color to the limits of MIL-STD-104 shall not be required after life cycle oven exposure.
Color striping or banding durability: 125 cycles (250 strokes) (min), Table III.
Dielectric test after immersion: 2500 volts (rms), 60 Hz.
Flammability: Quality conformance test, group II. For requirements and procedures see below.
Humidity resistance: After humidity exposure, wire shall meet the requirements for initial insulation resistance.
Identification of product: Not required for sizes 24 and smaller. Color code designator not required.
Identification durability: 125 cycles (250 strokes) (min), Table III.
Immersion: For procedure see below.
Impulse dielectric test: 8.0 kilovolts (peak), 100 percent test.
Insulation resistance, initial: 5000 megohms for 1000 feet (min).
Insulation thickness: 0.00[illegible] inch (min)
Lamination sealing: Oven temp, 230 ± 2°C (446 ± 3.6°F) for 48 hours.
Life cycle: 500 hours at 230°C ± 3°C (446°F ± 5.4°F). Dielectric test, 2500 volts (rms), 60 Hz. Procedure to use mandrels coated with polytetrafluoroethylene in the form of either enamel or wrapped tape, such that the diameter of the mandrels, after coating, still conform to the requirements of performance details, Table II.
Low temperature (cold bend):
Bend temperature, -65°C ± 3°C (-85°F ± 5.4°F).
Dielectric test, 2500 volts (rms), 60 Hz.
Shrinkage: 0.031 inch (max) at 230°C ± 3°C (446°F ± 5.4°F).
Solderability: See paragraph 4.6.3.

TABLE III. IMMERSION TEST FLUIDS

Test Fluid		Test Temperature	Immersion Time
a	MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	48°C to 50°C (118°F to 122°F)	20 hr
b	MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance	48°C to 50°C (118°F to 122°F)	20 hr
c	TT-I-735, Isopropyl Alcohol	20°C to 25°C (68°F to 77°F)	168 hr
d	MIL-T-5624, Turbine Fuel, Aviation, Grade JP-4	20°C to 25°C (68°F to 77°F)	168 hr
e	MIL-A- 8243, Anti-Icing and Deicing-Defrosting Fluid, Undiluted	48°C to 50°C (118°F to 122°F)	20 hr
f	MIL-A-8243, Anti-Icing and Deicing-Defrosting Fluid, Diluted 60/40 (Fluid/Water) Ratio	48°C to 50°C (118°F to 122°F)	20 hr
g	MIL-C-43616, Cleaning Compound, Aircraft Surface	48°C to 50°C (118°F to 122°F)	20 hr
h	TT-M-268, Methyl Isobutyl Ketone (For Use in Organic Coatings)	20°C to 25°C (68°F to 77°F)	168 hr
i	SAE-AS-1241, Fire Resistant Hydraulic Fluid for Aircraft	48°C to 50°C (118°F to 122°F)	20 hr
j	MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	118°C to 121°C (244°F to 250°F)	30 min
k	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Undiluted	63°C to 68°C (145°F to 154°F)	20 hr
l	MIL-C- 25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Diluted 25/75 (Fluid/Water) Ratio	63°C to 68°C (145°F to 154°F)	20 hr
m	TT-S-735, Standard Test Fluids; Hydrocarbon, Type I	20°C to 25°C (68°F to 77°F)	168 hr
n	TT-S-735, Standard Test Fluids; Hydrocarbon, Type II	20°C to 25°C (68°F to 77°F)	168 hr
o	TT-S-735, Standard Test Fluids; Hydrocarbon, Type III	20°C to 25°C (68°F to 77°F)	168 hr
p	TT-S-735, Standard Test Fluids; Hydrocarbon, Type VII	20°C to 25°C (68°F to 77°F)	168 hr
q	Dielectric-Coolant Fluid, Synthetic Silicate Ester Base, Monsanto Coolanol 25 or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
r	MIL-T-81533, 1, 1, 1 Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing	20°C to 25°C (68°F to 77°F)	168 hr
s	Azeotrope of Trichlorotrifluoroethane and Methylene Chloride, Dupont Freon TMC or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
t	MIL-G-3056, Gasoline, Automotive, Combat	20°C to 25°C (68°F to 77°F)	168 hr

GP13-0074-35-D/kas

Smoke: 250°C ± 5°C (482°F ± 9°F); no visible smoke.
Smoke quantity: D_S-20 min. shall not exceed 5.0.
Spark test of primary insulation: Not applicable.
Surface resistance: 5 megohms - inches (min), initial and final readings.
Thermal index: 200°C min for 15,000 hours (qualification only).
Thermal shock resistance:
  Oven temperature, 200°C ± 3°C (392°F ± 5.4°F).
  Maximum change in measurement, 0.060 inch.
Wrap back test: No cracking, no dielectric breakdown, oven temp. 200 ± 3°C (392 ± 5.4°F).

Flammability requirements and procedure:

The flammability test of MIL-W-22759 shall be modified for the wire of this specification sheet as follows: The specified test burner shall be used without the wing top flame spreader and shall be adjusted to furnish a 3-inch conical flame with an inner cone approximately 1 inch in height and a temperature of 955°C ± 30°C (1751°F ± 54°F) at its hottest point. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9-1/2 inches below the marked point on the wire specimen in the test chamber and at least 1/2 inch above the floor of the chamber. The period of application of the hot flame tip to the marked point on the wire specimen shall be 30 seconds for all sizes of wire. Observations shall include time of burning after removal of the test flame, final distance of flame travel on the wire above the test mark, and presence or absence of flame in the facial tissue due to incendiary drip from the specimen. Requirements shall be:

Duration of after-flame	3 seconds (max)
Flame travel	3.0 inches (max)
No flaming of tissue	

Breaking of the wire specimen in size 24 or smaller shall not be considered as failure provided the requirements for duration of flame, final distance of flame travel, and absence of incendiary dripping are met.

One specimen shall be tested from each sample unit. The post-flame dielectric test of MIL-W-22759 is not required for wire of this specification sheet.

Immersion procedure:

A 24-inch specimen for each test fluid in Table III shall have its diameter measured and shall then be immersed to within 6 inches of each end for the time and temperature specified. During immersion, the radius of bend of the wire shall be not less than 14 nor more than 35 times the specified maximum diameter of the wire under test. Upon removal from the test fluid, the specimen shall be wiped dry and then remain for 1 hour in free air at room temperature. The diameter shall be measured and compared to the initial diameter. The insulation shall be removed for a distance of 1/2 inch from each end of the specimen. The specimen shall then be subjected to the bend test and dielectric test specified in the procedure for life cycle testing.

Qualifying activity: The activity responsible for the qualified products covered by this specification sheet is Naval Avionics Center, Code 8/714, 6000 East 21st Street, Indianapolis, IN 46219-2189

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC, PTFE/POLYIMIDE/PTFE AND PTFE INSULATED, LIGHTWEIGHT, SILVER COATED COPPER CONDUCTOR, 200°C, 600 VOLTS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the wire described herein shall consist of this specification and the latest issue of MIL-W-22759

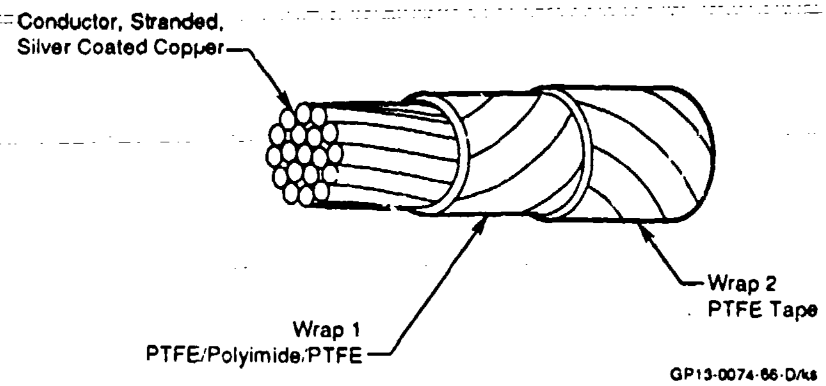


Figure 1. General Configuration

TABLE I. CONSTRUCTION DETAILS

Part No. 1/	Wire Size (AWG)	Conductor: Stranding (Number of Strands x AWG Gauge of Strands)	Conductor: Diameter (in.) Min	Conductor: Diameter (in.) Max	Finished Wire: Resistance at 20°C (68°F) (ohms/1,000 ft) (Max)	Finished Wire: Diameter (in.) Min	Finished Wire: Diameter (in.) Max	Finished Wire: Weight (lb/1,000 ft) (Max)	Insulation Tapes: Wrap 1 Tape Code	Insulation Tapes: Wrap 2 Tape Code
M22759/ -26-*	26	19 x 38	0.018	0.019	38.4	0.030	0.033	1.3	2/ 50% Min Overlap	3/ 50% Min Overlap
M22759/ -24-*	24	19 x 36	0.023	0.024	24.3	0.034	0.038	2.0		
M22759/ -22-*	22	19 x 34	0.029	0.030	15.1	0.039	0.043	2.9		
M22759/ -20-*	20	19 x 32	0.037	0.038	9.2	0.047	0.051	4.4		
M22759/ -18-*	18	19 x 30	0.046	0.048	6.6	0.056	0.060	6.7		
M22759/ -16-*	16	19 x 29	0.052	0.054	4.5	0.064	0.070	8.5		
M22759/ -14-*	14	19 x 27	0.065	0.068	2.9	0.077	0.083	12.8		
M22759/ -12-*	12	19x 25	0.084	0.087	1.8	0.097	0.103	20.1		
M22759/ -10-*	10	37 x 26	0.106	0.110	1.2	0.116	0.126	31.6		

GP13-0074-67-D/cjg

1/ Part number: The asterisks in the part number column, Tables I and II, shall be replaced by color code designators in accordance with MIL-STD-681. Examples: Size 20, white - M22759/ -20-9; white with orange stripe - M22759/ -20-93. Printing of color code designator on surface of wire insulation is not required.

2/ Tape code: .00025" PTFE fluorocarbon resin/.001" polyimide film/.00025" PTFE fluorocarbon resin.

3/ Tape code: .0015" PTFE (26-18); .002" PTFE (16-14); .0025" PTFE (12-10).

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

FSC 6145

TABLE II. TEST MANDREL AND TEST LOAD REQUIREMENTS

Wire Size (AWG)	Test Mandrel Diameter 1/ 2/ (in.)				Test Load 1/ (lb)		
	Life Cycle	Bend Test	Cold Bend	Wrap	Life Cycle	Bend Test	Cold Bend
26	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
24	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
22	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75
20	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75
18	0.375 (9.53)	0.375	0.375	0.250	1.00	1.00	1.00
16	0.375 (9.53)	0.375	0.375	0.250	1.00	1.00	1.00
14	0.500 (12.7)	0.500	0.500	0.375	2.00	2.00	2.00
12	0.750 (19.1)	0.750	0.750	0.375	2.00	2.00	2.00
10	0.750 (19.1)	0.750	0.750	0.375	3.00	3.00	3.00

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TABLE III. MARKING AND COLOR DURABILITY TEST LOADS

Wire Size (AWG)	Test Load 1/ (grams)
26 2/	75
24 2/	75
22	100
20	100
18	150
16	150
14	150
12	150
10	150

GP13-0074-69-D/kas

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Marking is not applicable.

RATINGS:

Temperature rating: 200°C (392°F) maximum continuous conductor temperature.
Voltage rating: 600 volts (rms) at sea level.

ADDITIONAL REQUIREMENTS:

Acid resistance: No requirement.
Arc propagation: No propagation or tracking (qualification only).
Blocking: 230°C ± 3°C (446°F ± 5.4°F).
Color: In accordance with MIL-STD-104, class 1; white preferred. Conformity of color to the limits of MIL-STD-104 shall not be required after life cycle oven exposure.
Color striping or banding durability: 125 cycles (250 strokes) (min), Table III.
Dielectric test after immersion: 2500 volts (rms), 60 Hz.
Flammability: Quality conformance test, group II. For requirements and procedures see below.
Humidity resistance: After humidity exposure, wire shall meet the requirements for initial insulation resistance.
Identification of product: Not required for sizes 24 and smaller. Color code designator not required.
Identification durability: 125 cycles (250 strokes) (min), Table III.
Immersion: For procedure see below.
Impulse dielectric test: 8.0 kilovolts (peak), 100 percent test.
Insulation resistance, initial: 5000 megohms for 1000 feet (min).
Insulation thickness: 0.005 inch (min)
Lamination sealing: Oven temp, 230 ± 2°C (446 ± 3.6°F) for 48 hours.

TABLE III. IMMERSION TEST FLUIDS

	Test Fluid	Test Temperature	Immersion Time
a	MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	48°C to 50°C (118°F to 122°F)	20 hr
b	MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance	48°C to 50°C (118°F to 122°F)	20 hr
c	TT-I-735, Isopropyl Alcohol	20°C to 25°C (68°F to 77°F)	168 hr
d	MIL-T-5624, Turbine Fuel, Aviation, Grade JP-4	20°C to 25°C (68°F to 77°F)	168 hr
e	MIL-A-8243, Anti-icing and Deicing-Defrosting Fluid, Undiluted	48°C to 50°C (118°F to 122°F)	20 hr
f	MIL-A-8243, Anti-icing and Deicing-Defrosting Fluid, Diluted 60/40 (Fluid/Water) Ratio	48°C to 50°C (118°F to 122°F)	20 hr
g	MIL-C-43616, Cleaning Compound, Aircraft Surface	48°C to 50°C (118°F to 122°F)	20 hr
h	TT-M-268, Methyl Isobutyl Ketone (For Use in Organic Coatings)	20°C to 25°C (68°F to 77°F)	168 hr
i	SAE-AS-1241, Fire Resistant Hydraulic Fluid for Aircraft	48°C to 50°C (118°F to 122°F)	20 hr
j	MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	118°C to 121°C (244°F to 250°F)	30 min
k	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Undiluted	63°C to 68°C (145°F to 154°F)	20 hr
l	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Diluted 25/75 (Fluid/Water) Ratio	63°C to 68°C (145°F to 154°F)	20 hr
m	TT-S-735, Standard Test Fluids; Hydrocarbon, Type I	20°C to 25°C (68°F to 77°F)	168 hr
n	TT-S-735, Standard Test Fluids; Hydrocarbon, Type II	20°C to 25°C (68°F to 77°F)	168 hr
o	TT-S-735, Standard Test Fluids; Hydrocarbon, Type III	20°C to 25°C (68°F to 77°F)	168 hr
p	TT-S-735, Standard Test Fluids; Hydrocarbon, Type VII	20°C to 25°C (68°F to 77°F)	168 hr
q	Dielectric-Coolant Fluid, Synthetic Silicate Ester Base, Monsanto Coolanol 25 or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
r	MIL-T-81533, 1, 1, 1 Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing	20°C to 25°C (68°F to 77°F)	168 hr
s	Azeotrope of Trichlorotrifluoroethane and Methylene Chloride, Dupont Freon TMC or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
t	MIL-G-3056, Gasoline, Automotive, Combat	20°C to 25°C (68°F to 77°F)	168 hr

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Life cycle: 500 hours at 230°C ± 3°C (446°F ± 5.4°F). Dielectric test, 2500 volts (rms), 60 Hz. Procedure to use mandrels coated with polytetrafluoroethylene in the form of either enamel or wrapped tape, such that the diameter of the mandrels, after coating, still conform to the requirements of performance details, Table II.
Low temperature (cold bend):
Bend temperature, -65°C ± 3°C (-85°F ± 5.4°F).
Dielectric test, 2500 volts (rms), 60 Hz.
Shrinkage: 0.031 inch (max) at 230°C ± 3°C (446°F ± 5.4°F).
Solderability: See paragraph 4.6.3.
Smoke: 250°C ± 5°C (482°F ± 9°F); no visible smoke.
Smoke quantity: D_s-20 min. shall not exceed 5.0.
Spark test of primary insulation: Not applicable.
Surface resistance: 5 megohms - inches (min), initial and final readings.
Thermal index: 200°C min for 15,000 hours (qualification only).
Thermal shock resistance:
Oven temperature, 200°C ± 3°C (392°F ± 5.4°F).
Maximum change in measurement, 0.060 inch.
Wrap back test: No cracking, no dielectric breakdown, oven temp. 200 ± 3°C (392 ± 5.4°F).

Flammability requirements and procedure:

The flammability test of MIL-W-22759 shall be modified for the wire of this specification sheet as follows: The specified test burner shall be used without the wing top flame spreader and shall be adjusted to furnish a 3-inch conical flame with an inner cone approximately 1 inch in height and a temperature of 955°C ± 30°C (1751°F ± 54°F) at its hottest point. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9-1/2 inches below the marked point on the wire specimen in the test chamber and at least 1/2 inch above the floor of the chamber. The period of application of the hot flame tip to the marked point on the wire specimen shall be 30 seconds for all sizes of wire. Observations shall include time of burning after removal of the test flame, final distance of flame travel on the wire above the test mark, and presence or absence of flame in the facial tissue due to incendiary drip from the specimen. Requirements shall be:

Duration of after-flame	3 seconds (max)
Flame travel	3.0 inches (max)
No flaming of tissue	

Breaking of the wire specimen in size 24 or smaller shall not be considered as failure provided the requirements for duration of flame, final distance of flame travel, and absence of incendiary dripping are met.

One specimen shall be tested from each sample unit. The post-flame dielectric test of MIL-W-22759 is not required for wire of this specification sheet.

Immersion procedure:

A 24-inch specimen for each test fluid in Table III shall have its diameter measured and shall then be immersed to within 6 inches of each end for the time and temperature specified. During immersion, the radius of bend of the wire shall be not less than 14 nor more than 35 times the specified maximum diameter of the wire under test. Upon removal from the test fluid, the specimen shall be wiped dry and then remain for 1 hour in free air at room temperature. The diameter shall be measured and compared to the initial diameter. The insulation shall be removed for a distance of 1/2 inch from each end of the specimen. The specimen shall then be subjected to the bend test and dielectric test specified in the procedure for life cycle testing.

Qualifying activity: The activity responsible for the qualified products covered by this specification sheet is Naval Avionics Center, Code B/714, 6000 East 21st Street, Indianapolis, IN 46219-2189.

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC,
PTFE/POLYIMIDE/PTFE, AND PTFE INSULATED,
NORMAL WEIGHT, SILVER COATED COPPER ALLOY CONDUCTOR, 200°C, 600 VOLTS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the wire described herein shall consist of this specification and the latest issue of MIL-W-22759.

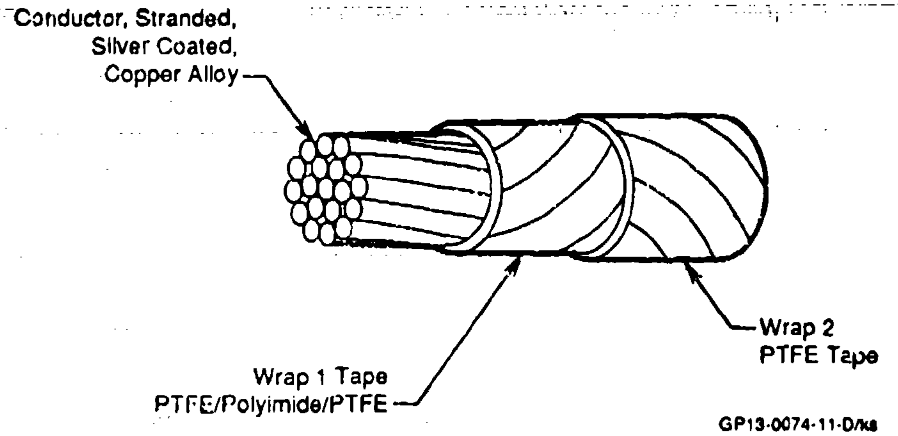

Figure 1. General Configuration

TABLE I. CONSTRUCTION DETAILS

Part No. 1/	Wire Size (AWG)	Conductor 2/ Stranding (Number of Strands x AWG Gauge of Strands)	Conductor Diameter of Stranded Conductor (in.) Min	Conductor Diameter of Stranded Conductor (in.) Max	Finished Wire Resistance at 20°C (68°F) (ohms/1,000 ft) (Max)	Finished Wire Diameter (in.) Min	Finished Wire Diameter (in.) Max	Finished Wire Weight (lb/1,000 ft) (Max)	Insulation Tapes Wrap 1	Insulation Tapes Wrap 2
M22759/ -26-*	26	19 x 38	0.018	0.019	61.3	0.033	0.037	1.5	3/ 50% Min Overlap	4/ 50% Min Overlap
M22759/ -24-*	24	19 x 36	0.023	0.024	28.4	0.038	0.042	2.2		
M22759/ -22-*	22	19 x 34	0.028	0.030	17.5	0.043	0.047	3.1		
M22759/ -20-*	20	19 x 32	0.037	0.038	10.7	0.051	0.055	4.6		

GP13-0074-12-D/ks

1/ Part number: The asterisks in the part number column, Tables I and II, shall be replaced by color code designators in accordance with MIL-STD-681. Examples: Size 20, white - M22759/ -20-9; white with orange stripe - M22759/ -20-93. Printing of color code designator on surface of wire insulation is not required.

2/ Conductor code: 20/22/24 AWG: High strength, silver coated, copper alloy, PD-135; 26 AWG: High strength, silver coated, copper alloy, CS-95.

3/ Tape code: 0.0005" PTFE fluorocarbon resin/ 0.001" polyimide film/ 0.0005" PTFE fluorocarbon resin.

4/ Tape code: 0.002" PTFE.

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

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TABLE II. TEST MANDREL AND TEST LOAD REQUIREMENTS

Wire Size (AWG)	Test Mandrel Diameter 1/ 2/ (in.)				Test Load 1/ (lb)		
	Life Cycle	Bend Test	Cold Bend	Wrap	Life Cycle	Bend Test	Cold Bend
26	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
24	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
22	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75
20	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75

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TABLE III. MARKING AND COLOR DURABILITY TEST LOADS

Wire Size (AWG)	Test Load 1/ (grams)
26 2/	75
24 2/	75
22	100
20	100

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Marking is not applicable.

RATINGS:

Temperature rating: 200°C (392°F) maximum continuous conductor temperature.
Voltage rating: 600 volts (rms) at sea level.

ADDITIONAL REQUIREMENTS:

Acid resistance: No requirement.
Arc propagation: No propagation or tracking (qualification only).
Blocking: 230°C ± 3°C (446°F ± 5.4°F).
Color: In accordance with MIL-STD-104, class 1; white preferred. Conformity of color to the limits of MIL-STD-104 shall not be required after life cycle oven exposure.
Color striping or banding durability: 125 cycles (250 strokes) (min), Table III.
Dielectric test after immersion: 2500 volts (rms), 60 Hz.
Flammability: Quality conformance test, group II. For requirements and procedures see below.
Humidity resistance: After humidity exposure, wire shall meet the requirements for initial insulation resistance.
Identification of product: Not required for sizes 24 and smaller. Color code designator not required.
Identification durability: 125 cycles (250 strokes) (min), Table III.
Immersion: For procedure see below.
Impulse dielectric test: 8.0 kilovolts (peak), 100 percent test.
Insulation resistance, initial: 5000 megohms for 1000 feet (min).
Insulation thickness: 0.0075 inch minimum
Lamination sealing: Oven temp, 230 ± 2°C (446 ± 3.6°F) for 48 hours.
Life cycle: 500 hours at 230°C ± 3°C (446°F ± 5.4°F). Dielectric test, 2500 volts (rms), 60 Hz. Procedure to use mandrels coated with polytetrafluoroethylene in the form of either enamel or wrapped tape, such that the diameter of the mandrels, after coating, still conform to the requirements of performance details, Table II.
Low temperature (cold bend):
. Bend temperature, -65°C ± 3°C (-85°F ± 5.4°F).
Dielectric test, 2500 volts (rms), 60 Hz.
Shrinkage: 0.031 inch (max) at 230°C ± 3°C (446°F ± 5.4°F).
Solderability: See paragraph 4.6.3.

TABLE III. IMMERSION TEST FLUIDS

	Test Fluid	Test Temperature	Immersion Time
a	MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	48°C to 50°C (118°F to 122°F)	20 hr
b	MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance	48°C to 50°C (118°F to 122°F)	20 hr
c	TT-I-735, Isopropyl Alcohol	20°C to 25°C (68°F to 77°F)	168 hr
d	MIL-T-5624, Turbine Fuel, Aviation, Grade JP-4	20°C to 25°C (68°F to 77°F)	168 hr
e	MIL-A-8243, Anti-Icing and Deicing-Defrosting Fluid, Undiluted	48°C to 50°C (118°F to 122°F)	20 hr
f	MIL-A-8243, Anti-Icing and Deicing-Defrosting Fluid, Diluted 60/40 (Fluid/Water) Ratio	48°C to 50°C (118°F to 122°F)	20 hr
g	MIL-C-43616, Cleaning Compound, Aircraft Surface	48°C to 50°C (118°F to 122°F)	20 hr
h	TT-M-268, Methyl Isobutyl Ketone (For Use in Organic Coatings)	20°C to 25°C (68°F to 77°F)	168 hr
i	SAE-AS-1241, Fire Resistant Hydraulic Fluid for Aircraft	48°C to 50°C (118°F to 122°F)	20 hr
j	MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	118°C to 121°C (244°F to 250°F)	30 min
k	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Undiluted	63°C to 68°C (145°F to 154°F)	20 hr
l	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Diluted 25/75 (Fluid/Water) Ratio	63°C to 68°C (145°F to 154°F)	20 hr
m	TT-S-735, Standard Test Fluids; Hydrocarbon, Type I	20°C to 25°C (68°F to 77°F)	168 hr
n	TT-S-735, Standard Test Fluids; Hydrocarbon, Type II	20°C to 25°C (68°F to 77°F)	168 hr
o	TT-S-735, Standard Test Fluids; Hydrocarbon, Type III	20°C to 25°C (68°F to 77°F)	168 hr
p	TT-S-735, Standard Test Fluids; Hydrocarbon, Type VII	20°C to 25°C (68°F to 77°F)	168 hr
q	Dielectric-Coolant Fluid, Synthetic Silicate Ester Base, Monsanto Coolanol 25 or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
r	MIL-T-81533, 1, 1, 1 Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing	20°C to 25°C (68°F to 77°F)	168 hr
s	Azeotrope of Trichlorotriflouroethane and Methylene Chloride, Dupont Freon TMC or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
t	MIL-G-3056, Gasoline, Automotive, Combat	20°C to 25°C (68°F to 77°F)	168 hr

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Smoke: 250°C ± 5°C (482°F ± 9°F); no visible smoke.
Smoke quantity: D_s-20 min. shall not exceed 5.0 for 22 AWG.
Spark test of primary insulation: Not applicable.
Surface resistance: 5 megohms - inches (min), initial and final readings.
Thermal index: 200°C min for 15,000 hours (qualification only).
Thermal shock resistance:
Oven temperature, 200°C ± 3°C (392°F ± 5.4°F).
Maximum change in measurement, 0.060 inch.
Wrap back test: No cracking, no dielectric breakdown, oven temp. 200 ± 3°C (392 ± 5.4°F).

Flammability requirements and procedure:

The flammability test of MIL-W-22759 shall be modified for the wire of this specification sheet as follows: The specified test burner shall be used without the wing top flame spreader and shall be adjusted to furnish a 3-inch conical flame with an inner cone approximately 1 inch in height and a temperature of 955°C ± 30°C (1751°F ± 54°F) at its hottest point. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9-1/2 inches below the marked point on the wire specimen in the test chamber and at least 1/2 inch above the floor of the chamber. The period of application of the hot flame tip to the marked point on the wire specimen shall be 30 seconds for all sizes of wire. Observations shall include time of burning after removal of the test flame, final distance of flame travel on the wire above the test mark, and presence or absence of flame in the facial tissue due to incendiary drip from the specimen. Requirements shall be:

Duration of after-flame	3 seconds (max)
Flame travel	3.0 inches (max)
No flaming of tissue	

Breaking of the wire specimen in size 24 or smaller shall not be considered as failure provided the requirements for duration of flame, final distance of flame travel, and absence of incendiary dripping are met.

One specimen shall be tested from each sample unit. The post-flame dielectric test of MIL-W-22759 is not required for wire of this specification sheet.

Immersion procedure:

A 24-inch specimen for each test fluid in Table III shall have its diameter measured and shall then be immersed to within 6 inches of each end for the time and temperature specified. During immersion, the radius of bend of the wire shall be not less than 14 nor more than 35 times the specified maximum diameter of the wire under test. Upon removal from the test fluid, the specimen shall be wiped dry and then remain for 1 hour in free air at room temperature. The diameter shall be measured and compared to the initial diameter. The insulation shall be removed for a distance of 1/2 inch from each end of the specimen. The specimen shall then be subjected to the bend test and dielectric test specified in the procedure for life cycle testing.

Qualifying activity: The activity responsible for the qualified products covered by this specification sheet is Naval Avionics Center, Code B/714, 6000 East 21st Street, Indianapolis, IN 46219-2189.

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC, PTFE/POLYIMIDE/PTFE, AND PTFE INSULATED NORMAL WEIGHT, SILVER PLATED COPPER CONDUCTOR, 200°C, 600 VOLTS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the wire described herein shall consist of this specification and the latest issue of MIL-W-22759

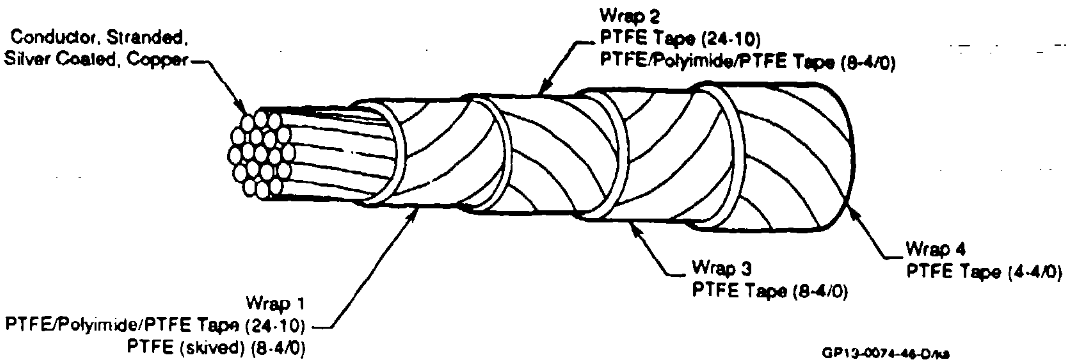

Figure 1. General Configuration

TABLE I. CONSTRUCTION DETAILS

Part No 1/	Wire Size (AWG)	Conductor			Finished Wire				Insulation Tapes			
		Stranding (Number of Strands x AWG Gauge of Strands)	Diameter (in.) Min	Diameter (in.) Max	Resistance at 20°C (68°F) (ohms/1,000 ft) (Max)	Diameter (in.) Min	Diameter (in.) Max	Weight (lb/1,000 ft) (Max)	Wrap 1 50% Min Overlap	Wrap 2 50% Min Overlap	Wrap 3 50% Min Overlap	Wrap 4 50% Min Overlap
M22759/ -24-*	24	19 x 36	0.023	0.024	24.300	0.038	0.042	2.2	2/	3/		
M22759/ -22-*	22	19 x 34	0.029	0.030	15.100	0.043	0.047	3.1				
M22759/ -20-*	20	19 x 32	0.037	0.038	9.190	0.051	0.055	4.8				
M22759/ -18-*	18	19 x 30	0.046	0.048	5.790	0.060	0.064	7.1				
M22759/ -16-*	16	19 x 29	0.052	0.054	4.520	0.067	0.073	8.9	2/	4/		
M22759/ -14-*	14	19 x 27	0.065	0.068	2.880	0.080	0.086	13.1				
M22759/ -12-*	12	37 x 28	0.084	0.087	1.900	0.101	0.107	20.6	2/	5/		
M22759/ -10-*	10	37 x 26	0.106	0.110	1.190	0.122	0.130	32.0				
M22759/ -8-*	8	133 x 29	0.158	0.166	0.658	0.180	0.188	57.6	6/	2/	6/	
M22759/ -6-*	6	133 x 27	0.198	0.208	0.418	0.219	0.228	87.9				
M22759/ -4-*	4	133 x 25	0.250	0.263	0.264	0.276	0.288	140.4	7/	2/	5/	5/
M22759/ -2-*	2	665 x 30	0.320	0.340	0.170	0.344	0.364	223.8				
M22759/ -1-*	1	817 x 30	0.360	0.380	0.139	TBD	TBD	TBD				
M22759/ -01-*	0	1045 x 30	0.405	0.425	0.108	0.420	0.450	345.8				
M22759/ -02-*	00	1330 x 30	0.450	0.475	0.085	0.465	0.495	438.8				

1/ Part number: The asterisks in the part number column, Tables I and II, shall be replaced by color code designators in accordance with MIL-STD-681 except that for sizes 2 and larger, the braid color shall be dark green and the designator shall be 50. Examples: Size 20, white with orange stripe - M22759/ -20-93; size 2, dark green - M22759/ -2-50. Printing of color code designator on surface of wire insulation is not required.

2/ Tape code: .0005" PTFE fluorocarbon resin/.001 "polyimide film/.0005" PTFE fluorocarbon resin.

3/ Tape code: .002" PTFE unsintered.

4/ Tape code: .0025" PTFE unsintered.

5/ Tape code: .003" PTFE unsintered.

6/ Tape code: .001" PTFE skived.

7/ Tape code: .002" PTFE skived.

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

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TABLE II. TEST MANDREL AND TEST LOAD REQUIREMENTS

Wire Size (AWG)	Test Mandrel Diameter 1/ (in.)			Test Load 1/ (lb)	
	Life Cycle	Bend Tests	Wrap	Life Cycle	Bend Tests
26	0.250	0.250	0.125	0.50	0.50
24	0.250	0.250	0.125	0.50	0.50
22	0.250	0.250	0.125	0.75	0.75
20	0.250	0.250	0.125	0.75	0.75
18	0.375	0.375	0.250	1.00	1.00
16	0.375	0.375	0.250	1.00	1.00
14	0.500	0.500	0.375	2.00	2.00
12	0.750	0.750	0.375	2.00	2.00
10	0.750	0.750	0.375	3.00	3.00
8	2.000	2.000	1.000	3.00	3.00
6	4.500	4.500	2.500	3.00	3.00
4	6.000	6.000	3.000	4.00	4.00
2	6.000	6.000	4.000	6.00	6.00
1	TBD	TBD	TBD	TBD	TBD
0	↓	↓	↓	↓	↓
00					

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TABLE III. MARKING AND COLOR DURABILITY TEST LOADS

Wire Size (AWG)	Test Load 1/ (grams)
26 2/	75
24 2/	75
22	100
20	100
18	150
16	150
14	150
12	150
10	150
8	TBD
6	↓
4	
2	

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Marking is not applicable.

RATINGS:

Temperature rating: 200°C (392°F) maximum continuous conductor temperature.
Voltage rating: 600 volts (rms) at sea level.

ADDITIONAL REQUIREMENTS:

Acid resistance: No requirement.
Arc propagation: No propagation or tracking (qualification only).
Blocking: 230°C ± 3°C (446°F ± 5.4°F).
Color: In accordance with MIL-STD-104, class 1; white preferred. For braided constructions, color shall be dark green within Munsell color limits of 5Y 3/2 and 5B 2/0.5. Conformity of color to the limits of MIL-STD-104 shall not be required after life cycle oven exposure.
Color striping or banding durability: 125 cycles (250 strokes) (min), Table III. Not required for sizes 2 and larger.
Dielectric test after immersion: 2500 volts (rms), 60 Hz.
Flammability: Quality conformance test, group II. For requirements and procedures see below.
Humidity resistance: After humidity exposure, wire shall meet the requirements for initial insulation resistance.
Identification of product: Not required for sizes 24 and smaller. Color code designator not required.
Identification durability: 125 cycles (250 strokes) (min), Table III. Not required for sizes 2 and larger.
Immersion: For procedure see below.
Impulse dielectric test: 8.0 kilovolts (peak), 100 percent test.
Insulation resistance, initial:
Sizes 26 through 10, 5000 megohms for 1000 feet (min).
Sizes 8 through 00, 3000 megohms for 1000 feet (min).
Insulation thickness: 0.0075 inch minimum
Lamination sealing: Oven temp 230 ± 2°C (446 ± 3.6°F) for 48 hours.
Life cycle: 500 hours at 230°C ± 3°C (446°F ± 5.4°F). Dielectric test, 2500 volts (rms), 60 Hz. Procedure to use mandrels coated with polytetrafluoroethylene in the form of either enamel or wrapped tape, such that the diameter of the mandrels, after coating, still conform to the requirements of performance details, Table II.
Low temperature (cold bend):
Bend temperature, -65°C ± 3°C (-85°F ± 5.4°F).
Dielectric test, 2500 volts (rms), 60 Hz.

TABLE III. IMMERSION TEST FLUIDS

	Test Fluid	Test Temperature	Immersion Time
a	MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	48°C to 50°C (118°F to 122°F)	20 hr
b	MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance	48°C to 50°C (118°F to 122°F)	20 hr
c	TT-I-735, Isopropyl Alcohol	20°C to 25°C (68°F to 77°F)	168 hr
d	MIL-T-5624, Turbine Fuel, Aviation, Grade JP-4	20°C to 25°C (68°F to 77°F)	168 hr
e	MIL-A- 8243, Anti-Icing and Deicing-Defrosting Fluid, Undiluted	48°C to 50°C (118°F to 122°F)	20 hr
f	MIL-A-8243, Anti-Icing and Deicing-Defrosting Fluid, Diluted 60/40 (Fluid/Water) Ratio	48°C to 50°C (118°F to 122°F)	20 hr
g	MIL-C-43616, Cleaning Compound, Aircraft Surface	48°C to 50°C (118°F to 122°F)	20 hr
h	TT-M-268, Methyl Isobutyl Ketone (For Use in Organic Coatings)	20°C to 25°C (68°F to 77°F)	168 hr
i	SAE-AS-1241, Fire Resistant Hydraulic Fluid for Aircraft	48°C to 50°C (118°F to 122°F)	20 hr
j	MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	118°C to 121°C (244°F to 250°F)	30 min
k	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Undiluted	63°C to 68°C (145°F to 154°F)	20 hr
l	MIL-C- 25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Diluted 25/75 (Fluid/Water) Ratio	63°C to 68°C (145°F to 154°F)	20 hr
m	TT-S-735, Standard Test Fluids; Hydrocarbon, Type I	20°C to 25°C (68°F to 77°F)	168 hr
n	TT-S-735, Standard Test Fluids; Hydrocarbon, Type II	20°C to 25°C (68°F to 77°F)	168 hr
o	TT-S-735, Standard Test Fluids; Hydrocarbon, Type III	20°C to 25°C (68°F to 77°F)	168 hr
p	TT-S-735, Standard Test Fluids; Hydrocarbon, Type VII	20°C to 25°C (68°F to 77°F)	168 hr
q	Dielectric-Coolant Fluid, Synthetic Silicate Ester Base, Monsanto Coolanol 25 or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
r	MIL-T-81533, 1, 1, 1 Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing	20°C to 25°C (68°F to 77°F)	168 hr
s	Azeotrope of Trichlorotrifluoroethane and Methylene Chloride Dupont Freon TMC or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
t	MIL-G-3056, Gasoline, Automotive, Combat	20°C to 25°C (68°F to 77°F)	168 hr

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Shrinkage: 0.031 inch (max) at 230°C ± 3°C (446°F ± 5.4°F).
Solderability: See paragraph 4.6.3.
Smoke: 250°C ± 5°C (482°F ± 9°F); no visible smoke.
Smoke quantity: D_s-20 min. shall not exceed 5.0 for 22 AWG.
Spark test of primary insulation: Not applicable.
Surface resistance: 500 megohms - inches (min), initial and final readings.
Thermal index: 200°C min for 15,000 hours (qualification only).
Thermal shock resistance:
  Oven temperature, 200°C ± 3°C (392°F ± 5.4°F).
  Maximum change in measurement, 0.060 inch.
Wrap back test: No cracking, no dielectric breakdown, oven temp. 200 ± 3°C (392 ± 5.4°F).

Flammability requirements and procedure:

The flammability test of MIL-W-22759 shall be modified for the wire of this specification sheet as follows: The specified test burner shall be used without the wing top flame spreader and shall be adjusted to furnish a 3-inch conical flame with an inner cone approximately 1 inch in height and a temperature of 955°C ± 30°C (1751°F ± 54°F) at its hottest point. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9-1/2 inches below the marked point on the wire specimen in the test chamber and at least 1/2 inch above the floor of the chamber. The period of application of the hot flame tip to the marked point on the wire specimen shall be 30 seconds for all sizes of wire. Observations shall include time of burning after removal of the test flame, final distance of flame travel on the wire above the test mark, and presence or absence of flame in the facial tissue due to incendiary drip from the specimen. Requirements shall be:

Duration of after-flame	3 seconds (max)
Flame travel	3.0 inches (max)
No flaming of tissue	

Breaking of the wire specimen in size 24 or smaller shall not be considered as failure provided the requirements for duration of flame, final distance of flame travel, and absence of incendiary dripping are met.

One specimen shall be tested from each sample unit. The post-flame dielectric test of MIL-W-22759 is not required for wire of this specification sheet.

Immersion procedure:

A 24-inch specimen for each test fluid in Table III shall have its diameter measured and shall then be immersed to within 6 inches of each end for the time and temperature specified. During immersion, the radius of bend of the wire shall be not less than 14 nor more than 35 times the specified maximum diameter of the wire under test. Upon removal from the test fluid, the specimen shall be wiped dry and then remain for 1 hour in free air at room temperature. The diameter shall be measured and compared to the initial diameter. The insulation shall be removed for a distance of 1/2 inch from each end of the specimen. The specimen shall then be subjected to the bend test and dielectric test specified in the procedure for life cycle testing.

Qualifying activity: The activity responsible for the qualified products covered by this specification sheet is Naval Avionics Center, Code B/714, 6000 East 21st Street, Indianapolis, IN 46219-2189.

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC,
PTFE, FLUOROCARBON/POLYIMIDE, PTFE INSULATED,
LIGHTWEIGHT, SILVER COATED COPPER ALLOY CONDUCTOR, 200°C, 600 VOLTS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the wire described herein shall consist of this specification and the latest issue of MIL-W-22759

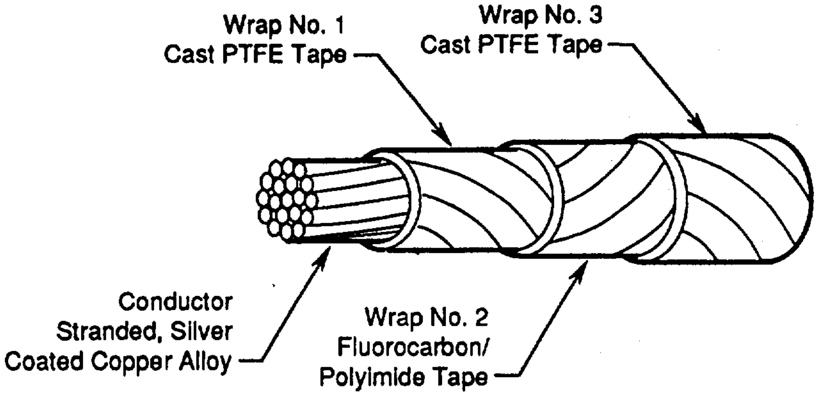

Figure 1. General Configuration

TABLE I. CONSTRUCTION DETAILS

Part No. 1/	Wire Size (AWG)	Conductor 2/ Stranding (Number of Strands x AWG Gauge of Strands)	Conductor Diameter (in.) Min	Conductor Diameter (in.) Max	Finished Wire Resistance at 20°C (68°F) (ohms/1,000 ft) (Max)	Finished Wire Diameter (in.) Min	Finished Wire Diameter (in.) Max	Finished Wire Weight (lb/1,000 ft) (Max)	Insulation Tapes Wrap 1	Insulation Tapes Wrap 2	Insulation Tapes Wrap 3
M22759/ -26-*	26	19 x 38	0.018	0.019	61.3	0.030	0.034	1.2	3/ 0.85 50% Min Overlap	4/ 1.25 50% Min Overlap	5/ 0.85 50% Min Overlap
M22759/ -24-*	24	19 x 36	0.023	0.024	28.4	0.033	0.036	1.8			
M22759/ -22-*	22	19 x 34	0.029	0.030	17.5	0.039	0.043	2.7			
M22759/ -20-*	20	19 x 32	0.037	0.038	10.7	0.048	0.052	4.3			

GP13-0074-37-D/cjg

1/ Part number: The asterisks in the part number column, Tables I and II, shall be replaced by color code designators in accordance with MIL-STD-681. Examples: Size 20, white - M22759/ -20-9; white with orange stripe - M22759/ -20-93. Printing of color code designator on surface of wire insulation is not required.

2/ Conductor code: 20/22/24 AWG: High strength, silver coated, copper alloy, PD-135; 26 AWG: High strength, silver coated, copper alloy, CS-95.

3/ Tape code: .85 - Cut thru resistant, heat resealable, cast PTFE tape, 0.00085" max. thickness.

4/ Tape code: 1.25 - 0.0001" PTFE fluorocarbon resin/ 0.001" polyimide film/ 0.0001" PTFE fluorocarbon resin, 0.00125" max. thickness.

5/ Tape code: .85 - Excimer laser markable, heat sealable, cast PTFE tape, 0.00085" max. thickness.

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

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TABLE II. TEST MANDREL AND TEST LOAD REQUIREMENTS

Wire Size (AWG)	Test Mandrel Diameter 1/ 2/ (in.)				Test Load 1/ (lb)		
	Life Cycle	Bend Test	Cold Bend	Wrap	Life Cycle	Bend Test	Cold Bend
26	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
24	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
22	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75
20	0.250 (6.35)	0 250	0.250	0.125	0.75	0.75	0.75

GP13-0074-38-D/kas

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Metric equivalents are in parentheses.

TABLE III. MARKING AND COLOR DURABILITY TEST LOADS

Wire Size (AWG)	Test Load 1/ (grams)
26 2/	75
24 2/	75
22	100
20	100

GP13-0074-39-D/kas

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Marking is not applicable.

RATINGS:

Temperature rating: 200°C (392°F) maximum continuous conductor temperature.
Voltage rating: 600 volts (rms) at sea level.

ADDITIONAL REQUIREMENTS:

Acid resistance: No requirement.
Arc propagation: No propagation or tracking (qualification only).
Blocking: 230°C ± 3°C (446°F ± 5.4°F).
Color: In accordance with MIL-STD-104, class 1; white preferred. Conformity of color to the limits of MIL-STD-104 shall not be required after life cycle oven exposure.
Color striping or banding durability: 125 cycles (250 strokes) (min), Table III.
Dielectric test after immersion: 2500 volts (rms), 60 Hz.
Flammability: Quality conformance test, group II. For requirements and procedures see below.
Humidity resistance: After humidity exposure, wire shall meet the requirements for initial insulation resistance.
Identification of product: Not required for sizes 24 and smaller. Color code designator not required.
Identification durability: 125 cycles (250 strokes) (min), Table III.
Immersion: For procedure see below.
Impulse dielectric test: 8.0 kilovolts (peak), 100 percent test.
Insulation resistance, initial: 5000 megohms for 1000 feet (min).
Insulation thickness: 0.005 inch (min)
Lamination sealing: Oven temp 230 ± 2°C (446 ± 3.6°F) for 48 hours.
Life cycle: 500 hours at 230°C ± 3°C (446°F ± 5.4°F). Dielectric test, 2500 volts (rms), 60 Hz. Procedure to use mandrels coated with polytetrafluoroethylene in the form of either enamel or wrapped tape, such that the diameter of the mandrels, after coating, still conform to the requirements of performance details, Table II.

TABLE III. IMMERSION TEST FLUIDS

	Test Fluid	Test Temperature	Immersion Time
a	MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	48°C to 50°C (118°F to 122°F)	20 hr
b	MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance	48°C to 50°C (118°F to 122°F)	20 hr
c	TT-I-735, Isopropyl Alcohol	20°C to 25°C (68°F to 77°F)	168 hr
d	MIL-T-5624, Turbine Fuel, Aviation, Grade JP-4	20°C to 25°C (68°F to 77°F)	168 hr
e	MIL-A-8243, Anti-Icing and Deicing-Defrosting Fluid, Undiluted	48°C to 50°C (118°F to 122°F)	20 hr
f	MIL-A-8243, Anti-Icing and Deicing-Defrosting Fluid, Diluted 60/40 (Fluid/Water) Ratio	48°C to 50°C (118°F to 122°F)	20 hr
g	MIL-C-43616, Cleaning Compound, Aircraft Surface	48°C to 50°C (118°F to 122°F)	20 hr
h	TT-M-268, Methyl Isobutyl Ketone (For Use in Organic Coatings)	20°C to 25°C (68°F to 77°F)	168 hr
i	SAE-AS-1241, Fire Resistant Hydraulic Fluid for Aircraft	48°C to 50°C (118°F to 122°F)	20 hr
j	MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	118°C to 121°C (244°F to 250°F)	30 min
k	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Undiluted	63°C to 68°C (145°F to 154°F)	20 hr
l	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Diluted 25/75 (Fluid/Water) Ratio	63°C to 68°C (145°F to 154°F)	20 hr
m	TT-S-735, Standard Test Fluids; Hydrocarbon, Type I	20°C to 25°C (68°F to 77°F)	168 hr
n	TT-S-735, Standard Test Fluids; Hydrocarbon, Type II	20°C to 25°C (68°F to 77°F)	168 hr
o	TT-S-735, Standard Test Fluids; Hydrocarbon, Type III	20°C to 25°C (68°F to 77°F)	168 hr
p	TT-S-735, Standard Test Fluids; Hydrocarbon, Type VII	20°C to 25°C (68°F to 77°F)	168 hr
q	Dielectric-Coolant Fluid, Synthetic Silicate Ester Base, Monsanto Coolanol 25 or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
r	MIL-T-81533, 1, 1, 1 Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing	20°C to 25°C (68°F to 77°F)	168 hr
s	Azeotrope of Trichlorotrifluoroethane and Methylene Chloride, Dupont Freon TMC or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
t	MIL-G-3056, Gasoline, Automotive, Combat	20°C to 25°C (68°F to 77°F)	168 hr

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Low temperature (cold bend):
  Bend temperature, -65°C ± 3°C (-85°F ± 5.4°F).
  Dielectric test, 2500 volts (rms), 60 Hz.
Shrinkage: 0.125 inch (max) at 230°C ± 3°C (446°F ± 5.4°F).
Solderability: See paragraph 4.6.3.
Smoke: 250°C ± 5°C (482°F ± 9°F); no visible smoke.
Smoke quantity: D_s-20 min. shall not exceed 5.0.
Spark test of primary insulation: Not applicable.
Surface resistance: 5 megohms - inches (min), initial and final readings.
Thermal index: 200°C min for 15,000 hours (qualification only).
Thermal shock resistance:
  Oven temperature, 200°C ± 3°C (392°F ± 5.4°F).
  Maximum change in measurement, 0.060 inch.
Wrap back test: No cracking, no dielectric breakdown, oven temp. 200 ± 3°C (392 ± 5.4°F).

Flammability requirements and procedure:

The flammability test of MIL-W-22759 shall be modified for the wire of this specification sheet as follows: The specified test burner shall be used without the wing top flame spreader and shall be adjusted to furnish a 3-inch conical flame with an inner cone approximately 1 inch in height and a temperature of 955°C ± 30°C (1751°F ± 54°F) at its hottest point. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9-1/2 inches below the marked point on the wire specimen in the test chamber and at least 1/2 inch above the floor of the chamber. The period of application of the hot flame tip to the marked point on the wire specimen shall be 30 seconds for all sizes of wire. Observations shall include time of burning after removal of the test flame, final distance of flame travel on the wire above the test mark, and presence or absence of flame in the facial tissue due to incendiary drip from the specimen. Requirements shall be:

Duration of after-flame	3 seconds (max)
Flame travel	3.0 inches (max)
No flaming of tissue	

Breaking of the wire specimen in size 24 or smaller shall not be considered as failure provided the requirements for duration of flame, final distance of flame travel and absence of incendiary dripping are met.

One specimen shall be tested from each sample unit. The post-flame dielectric test of MIL-W-22759 is not required for wire of this specification sheet.

Immersion procedure:

A 24-inch specimen for each test fluid in Table III shall have its diameter measured and shall then be immersed to within 6 inches of each end for the time and temperature specified. During immersion, the radius of bend of the wire shall be not less than 14 nor more than 35 times the specified maximum diameter of the wire under test. Upon removal from the test fluid, the specimen shall be wiped dry and then remain for 1 hour in free air at room temperature. The diameter shall be measured and compared to the initial diameter. The insulation shall be removed for a distance of 1/2 inch from each end of the specimen. The specimen shall then be subjected to the bend test and dielectric test specified in the procedure for life cycle testing.

Qualifying activity: The activity responsible for the qualified products covered by this specification sheet is ''val Avionics Center, Code B/714, 6000 East 21st Street, Indianapolis, IN 46219-2189.

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC, PTFE, FLUOROCARBON/POLYIMIDE, PTFE INSULATED, LIGHTWEIGHT, SILVER COATED COPPER CONDUCTOR, 200°C, 600 VOLTS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the wire described herein shall consist of this specification and the latest issue of MIL-W-22759

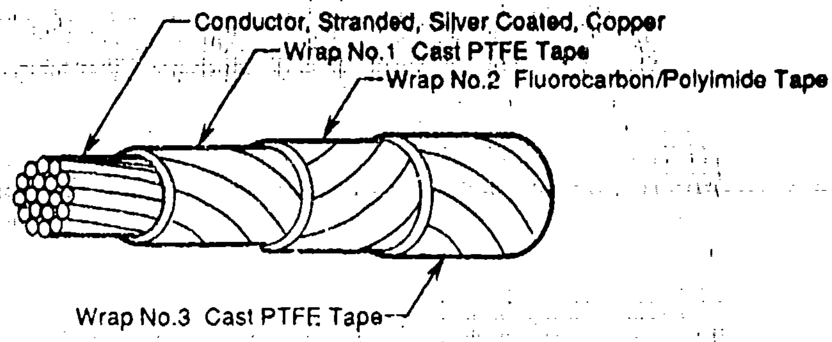

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Figure 1. General Configuration

TABLE I CONSTRUCTION DETAILS

Part No. 1/	Wire Size (AWG)	Conductor			Finished Wire				Insulation Tapes		
		Stranding (Number of Strands X AWG Gauge of Strands)	Diameter (in.)		Resistance at 20°C (ohms/1,000 ft) (Max)	Diameter (in.)		Weight (lb/1,000 ft) (Max)	Wrap 1	Wrap 2	Wrap 3
			Min	Max		Min	Max		Tape Code	Tape Code	Tape Code
M22759/ -26-*	26	19 x 38	0.018	0.019	38.40	0.030	0.033	1.2	2/ 0.85	3/ 1.25	4/ 0.85
M22759/ -24-*	24	19 x 36	0.023	0.024	24.30	0.033	0.036	1.7			
M22759/ -22-*	22	19 x 34	0.029	0.030	15.10	0.039	0.043	2.6			
M22759/ -20-*	20	19 x 32	0.037	0.038	9.19	0.043	0.051	4.2			
M22759/ -18-*	18	19 x 30	0.046	0.048	5.79	0.059	0.062	6.5	5/ 1.5		
M22759/ -16-*	16	19 x 29	0.052	0.054	4.52	0.068	0.071	8.4			
M22759/ -14-*	14	19 x 27	0.065	0.068	2.88	0.081	0.084	12.8			
M22759/ -12-*	12	37 x 28	0.084	0.087	1.80	0.101	0.104	19.6			
M22759/ -10-*	10	37 x 26	0.106	0.110	1.19	0.124	0.128	30.5			

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1/ Part number: The asterisks in the part number column, Tables I and II, shall be replaced by color code designators in accordance with MIL-STD-681. Examples: Size 20, white - M22759/ -20-9; white with orange stripe - M22759/ -20-93. Printing of color code designator on surface of wire insulation is not required.

2/ Tape code: .85 - Cut thru resistant, heat resealable, cast PTFE tape, 0.00085" max. thickness, 50% min. overlap.

3/ Tape code: 1.25 - 0.0001" PTFE fluorocarbon resin/ 0.001" aromatic polyimide film/ 0.0001" mil PTFE fluorocarbon resin, 0.00125" max. thickness, 50% min. overlap.

4/ Tape code: .85 - Laser markable, heat sealable, cast PTFE tape, 0.00085" max. thickness, 50% min. overlap. (66% min. overlap on 10 and 12 AWG).

5/ Tape code: 1.5 - Heat resealable, cast PTFE tape, 0.0015" max. thickness, 66% min. overlap.

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

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TABLE II. TEST MANDREL AND TEST LOAD REQUIREMENTS

Wire Size (AWG)	Test Mandrel Diameter 1/ 2/ (in.)				Test Load 1/ (lb)		
	Life Cycle	Bend Test	Cold Bend	Wrap	Life Cycle	Bend Test	Cold Bend
26	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
24	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
22	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75
20	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75
18	0.375 (9.53)	0.375	0.375	0.250	1.00	1.00	1.00
16	0.375 (9.53)	0.375	0.375	0.250	1.00	1.00	1.00
14	0.500 (12.7)	0.500	0.500	0.375	2.00	2.00	2.00
12	0.750 (19.1)	0.750	0.750	0.375	2.00	2.00	2.00
10	0.750 (19.1)	0.750	0.750	0.375	3.00	3.00	3.00

GP13-0074-63-D/kas

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Metric equivalents are in parentheses.

TABLE III. MARKING AND COLOR DURABILITY TEST LOADS

Wire Size (AWG)	Test Load 1/ (grams)
26 2/	75
24 2/	75
22	100
20	100
18	150
16	150
14	150
12	150
10	150

GP13-0074-64-D/kas

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Marking is not applicable.

RATINGS:

Temperature rating: 200°C (392°F) maximum continuous conductor temperature.
Voltage rating: 600 volts (rms) at sea level.

ADDITIONAL REQUIREMENTS:

Acid resistance: No requirement.
Arc propagation: No propagation or tracking (qualification only).
Blocking: 230°C ± 3°C (446°F ± 5.4°F).
Color: In accordance with MIL-STD-104, class 1; white preferred. Conformity of color to the limits of MIL-STD-104 shall not be required after life cycle oven exposure.
Color striping or banding durability: 125 cycles (250 strokes) (min), Table III.
Dielectric test after immersion: 2500 volts (rms), 60 Hz.
Flammability: Quality conformance test, group II. For requirements and procedures see below.
Humidity resistance: After humidity exposure, wire shall meet the requirements for initial insulation resistance.
Identification of product: Not required for sizes 24 and smaller. Color code designator not required.
Identification durability: 125 cycles (250 strokes) (min), Table III.
Immersion: For procedure see below.
Impulse dielectric test: 8.0 kilovolts (peak), 100 percent test.
Insulation resistance, initial: 5000 megohms for 1000 feet (min).
Insulation thickness: 0.005 inch (min)
Lamination sealing: Oven temp 230 ± 2°C (446 ± 3.6°F) for 48 hours.

TABLE III. IMMERSION TEST FLUIDS

	Test Fluid	Test Temperature	Immersion Time
a	MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	48°C to 50°C (118°F to 122°F)	20 hr
b	MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance	48°C to 50°C (118°F to 122°F)	20 hr
c	TT-I-735, Isopropyl Alcohol	20°C to 25°C (68°F to 77°F)	168 hr
d	MIL-T-5624, Turbine Fuel, Aviation, Grade JP-4	20°C to 25°C (68°F to 77°F)	168 hr
e	MIL-A- 8243, Anti-Icing and Deicing-Defrosting Fluid, Undiluted	48°C to 50°C (118°F to 122°F)	20 hr
f	MIL-A-8243, Anti-Icing and Deicing-Defrosting Fluid, Diluted 60/40 (Fluid/Water) Ratio	48°C to 50°C (118°F to 122°F)	20 hr
g	MIL-C-43616, Cleaning Compound, Aircraft Surface	48°C to 50°C (118°F to 122°F)	20 hr
h	TT-M-268, Methyl Isobutyl Ketone (For Use in Organic Coatings)	20°C to 25°C (68°F to 77°F)	168 hr
i	SAE-AS-1241, Fire Resistant Hydraulic Fluid for Aircraft	48°C to 50°C (118°F to 122°F)	20 hr
j	MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	118°C to 121°C (244°F to 250°F)	30 min
k	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Undiluted	63°C to 68°C (145°F to 154°F)	20 hr
l	MIL-C- 25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Diluted 25/75 (Fluid/Water) Ratio	63°C to 68°C (145°F to 154°F)	20 hr
m	TT-S-735, Standard Test Fluids; Hydrocarbon, Type I	20°C to 25°C (68°F to 77°F)	168 hr
n	TT-S-735, Standard Test Fluids; Hydrocarbon, Type II	20°C to 25°C (68°F to 77°F)	168 hr
o	TT-S-735, Standard Test Fluids; Hydrocarbon, Type III	20°C to 25°C (68°F to 77°F)	168 hr
p	TT-S-735, Standard Test Fluids; Hydrocarbon, Type VII	20°C to 25°C (68°F to 77°F)	168 hr
q	Dielectric-Coolant Fluid, Synthetic Silicate Ester Base, Monsanto Coolanol 25 or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
r	MIL-T-81533, 1, 1, 1 Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing	20°C to 25°C (68°F to 77°F)	168 hr
s	Azeotrope of Trichlorotrifluoroethane and Methylene Chloride, Dupont Freon TMC or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
t	MIL-G-3056, Gasoline, Automotive, Combat	20°C to 25°C (68°F to 77°F)	168 hr

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Life cycle: 500 hours at 230°C ± 3°C (446°F ± 5.4°F). Dielectric test, 2500 volts (rms), 60 Hz. Procedure to use mandrels coated with polytetrafluoroethylene in the form of either enamel or wrapped tape, such that the diameter of the mandrels, after coating, still conform to the requirements of performance details, Table II.
Low temperature (cold bend):
Bend temperature, -65°C ± 3°C (-85°F ± 5.4°F).
Dielectric test, 2500 volts (rms), 60 Hz.
Shrinkage: 0.125 inch (max) at 230°C ± 3°C (446°F ± 5.4°F).
Solderability: See paragraph 4.6.3.
Smoke: 250°C ± 5°C (482°F ± 9°F); no visible smoke.
Smoke quantity: D_s-20 min. shall not exceed 5.0.
Spark test of primary insulation: Not applicable.
Surface resistance: 5 megohms - inches (min), initial and final readings.
Thermal index: 200°C min for 15,000 hours (qualification only).
Thermal shock resistance:
Oven temperature, 200°C ± 3°C (392°F ± 5.4°F).
Maximum change in measurement, 0.060 inch.
Wet Dielectric: 2500 watts (rms).
Wrap back test: No cracking, no dielectric breakdown, oven temp. 200 ± 3°C (392 ± 5.4°F).

Flammability requirements and procedure:

The flammability test of MIL-W-22759 shall be modified for the wire of this specification sheet as follows: The specified test burner shall be used without the wing top flame spreader and shall be adjusted to furnish a 3-inch conical flame with an inner cone approximately 1 inch in height and a temperature of 955°C ± 30°C (1751°F ± 54°F) at its hottest point. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9-1/2 inches below the marked point on the wire specimen in the test chamber and at least 1/2 inch above the floor of the chamber. The period of application of the hot flame tip to the marked point on the wire specimen shall be 30 seconds for all sizes of wire. Observations shall include time of burning after removal of the test flame, final distance of flame travel on the wire above the test mark, and presence or absence of flame in the facial tissue due to incendiary drip from the specimen. Requirements shall be:

Duration of after-flame	3 seconds (max)
Flame travel	3.0 inches (max)
No flaming of tissue	

Breaking of the wire specimen in size 24 or smaller shall not be considered as failure provided the requirements for duration of flame, final distance of flame travel, and absence of incendiary dripping are met.

One specimen shall be tested from each sample unit. The post-flame dielectric test of MIL-W-22759 is not required for wire of this specification sheet.

Immersion procedure:

A 24-inch specimen for each test fluid in Table III shall have its diameter measured and shall then be immersed to within 6 inches of each end for the time and temperature specified. During immersion, the radius of bend of the wire shall be not less than 14 nor more than 35 times the specified maximum diameter of the wire under test. Upon removal from the test fluid, the specimen shall be wiped dry and then remain for 1 hour in free air at room temperature. The diameter shall be measured and compared to the initial diameter. The insulation shall be removed for a distance of 1/2 inch from each end of the specimen. The specimen shall then be subjected to the bend test and dielectric test specified in the procedure for life cycle testing.

Qualifying activity: The activity responsible for the qualified products covered by this specification sheet is Naval Avionics Center, Code B/714, 6000 East 21st Street, Indianapolis, IN 46219-2189.

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC,
PTFE, FLUOROCARBON/POLYIMIDE, PTFE INSULATED,
NORMAL WEIGHT, SILVER COATED COPPER ALLOY CONDUCTOR, 200°C, 600 VOLTS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the wire described herein shall consist of this specification and the latest issue of MIL-W-22759

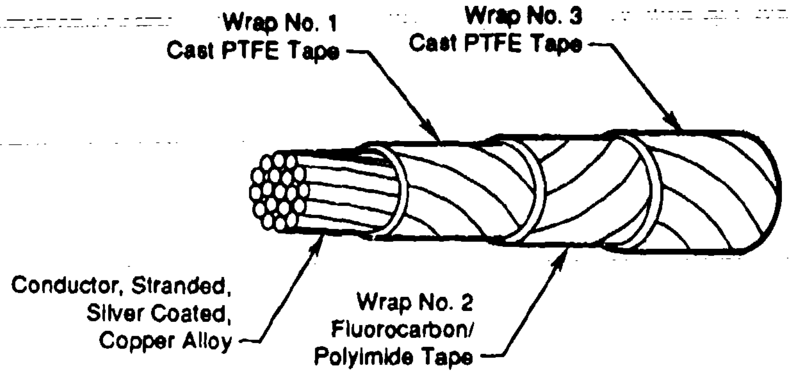

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Figure 1. General Configuration

TABLE I. CONSTRUCTION DETAILS

Part No. 1/	Wire Size (AWG)	Conductor 2/			Finished Wire				Insulation Tapes		
		Stranding (Number of Strands x AWG Gauge of Strands)	Diameter (in.)		Resistance at 20°C (68°F) (ohms/1,000 ft) (Max)	Diameter (in.)		Weight (lb/1,000 ft) (Max)	Wrap 1	Wrap 2	Wrap 3
			Min	Max		Min	Max				
M22759/ -26-*	26	19 x 38	0.018	0.019	61.3	0.033	0.035	1.5	3/ 50% Min Overlap	4/ 50% Min Overlap	5/ 50% Min Overlap
M22759/ -24-*	24	19 x 36	0.023	0.024	28.4	0.039	0.043	2.1			
M22759/ -22-*	22	19 x 34	0.029	0.030	17.5	0.044	0.048	3.1			
M22759/ -20-*	20	19 x 32	0.037	0.038	10.7	0.053	0.057	4.7			

GP13-0074-17-D/cjg

1/ Part number: The asterisks in the part number column, Tables I and II, shall be replaced by color code designators in accordance with MIL-STD-681. Examples: Size 20, white - M22759/ -20-9; white with orange stripe - M22759/ -20-93. Printing of color code designator on surface of wire insulation is not required.

2/ Conductor code: 20/22/24 AWG: High strength, silver coated, copper alloy, PD-135; 26 AWG: High strength, silver coated, copper alloy, CS-95.

3/ Tape code: 1.6 - Cut thru resistant, heat resealable, cast PTFE tape, 0.0016" max. thickness.

4/ Tape code: 1.25 - 0.0001" FEP fluorocarbon resin/ 0.001" polyimide film/ 0.0001" FEP fluorocarbon resin, 0.00125" max. thickness.

5/ Tape code: .85 - Laser markable, heat sealable, cast PTFE tape, 0.00085" max. thickness.

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TABLE II. TEST MANDREL AND TEST LOAD REQUIREMENTS

Wire Size (AWG)	Test Mandrel Diameter 1/ 2/ (in.)				Test Load 1/ (lb)		
	Life Cycle	Bend Test	Cold Bend	Wrap	Life Cycle	Bend Test	Cold Bend
26	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
24	0.250 (6.35)	0.250	0.250	0.125	0.50	0.50	0.50
22	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75
20	0.250 (6.35)	0.250	0.250	0.125	0.75	0.75	0.75

GP13-0074-18-D/kas

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Metric equivalents are in parentheses.

TABLE III. MARKING AND COLOR DURABILITY TEST LOADS

Wire Size (AWG)	Test Load 1/ (grams)
26 2/	75
24 2/	75
22	100
20	1C^

GP13-0074-19-D/kas

1/ Tolerance shall be +/- 3 percent of the given values.

2/ Marking is not applicable.

RATINGS:

Temperature rating: 200°C (392°F) maximum continuous conductor temperature.
Voltage rating: 600 volts (rms) at sea level.

ADDITIONAL REQUIREMENTS:

Acid resistance: No requirement.
Arc propagation: No propagation or tracking (qualification only).
Blocking: 230°C ± 3°C (446°F ± 5.4°F).
Color: In accordance with MIL-STD-104, class 1; white preferred. Conformity of color to the limits of MIL-STD-104 shall not be required after life cycle oven exposure.
Color striping or banding durability: 125 cycles (250 strokes) (min), Table III.
Dielectric test after immersion: 2500 volts (rms), 60 Hz.
Flammability: Quality conformance test, group II. For requirements and procedures see below.
Humidity resistance: After humidity exposure, wire shall meet the requirements for initial insulation resistance.
Identification of product: Not required for sizes 24 and smaller. Color code designator not required.
Identification durability: 125 cycles (250 strokes) (min), Table III.
Immersion: For procedure see below.
Impulse dielectric test: 8.0 kilovolts (peak), 100 percent test.
Insulation resistance, initial: 5000 megohms for 1000 feet (min).
Insulation thickness: 0.0075 inch minimum
Lamination sealing: Oven temp 230 ± 2°C (446 ± 3.6°F) for 48 hours.
Life cycle: 500 hours at 230°C ± 3°C (446°F ± 5.4°F). Dielectric test, 2500 volts (rms), 60 Hz. Procedure to use mandrels coated with polytetrafluoroethylene in the form of either enamel or wrapped tape, such that the diameter of the mandrels, after coating, still conform to the requirements of performance details, Table II.
Low temperature (cold bend):
  Bend temperature, -65°C ± 3°C (-85°F ± 5.4°F).
  Dielectric test, 2500 volts (rms), 60 Hz.
Shrinkage: 0.125 inch (max) at 230°C ± 3°C (446°F ± 5.4°F).

TABLE IIi. IMMERSION TEST FLUIDS

Test Fluid		Test Temperature	Immersion Time
a	MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	48°C to 50°C (118°F to 122°F)	20 hr
b	MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance	48°C to 50°C (118°F to 122°F)	20 hr
c	TT-I-735, Isopropyl Alcohol	20°C to 25°C (68°F to 77°F)	168 hr
d	MIL-T-5624, Turbine Fuel, Aviation, Grade JP-4	20°C to 25°C (68°F to 77°F)	168 hr
e	MIL-A-8243, Anti-Icing and Deicing-Defrosting Fluid, Undiluted	48°C to 50°C (118°F to 122°F)	20 hr
f	MIL-A-8243, Anti-Icing and Deicing-Defrosting Fluid, Diluted 60/40 (Fluid/Water) Ratio	48°C to 50°C (118°F to 122°F)	20 hr
g	MIL-C-43616, Cleaning Compound, Aircraft Surface	48°C to 50°C (118°F to 122°F)	20 hr
h	TT-M-268, Methyl Isobutyl Ketone (For Use in Organic Coatings)	20°C to 25°C (68°F to 77°F)	168 hr
i	SAE-AS-1241, Fire Resistant Hydraulic Fluid for Aircraft	48°C to 50°C (118°F to 122°F)	20 hr
j	MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	118°C to 121°C (244°F to 250°F)	30 min
k	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Undiluted	63°C to 68°C (145°F to 154°F)	20 hr
l	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Diluted 25/75 (Fluid/Water) Ratio	63°C to 68°C (145°F to 154°F)	20 hr
m	TT-S-735, Standard Test Fluids; Hydrocarbon, Type I	20°C to 25°C (68°F to 77°F)	168 hr
n	TT-S-735, Standard Test Fluids; Hydrocarbon, Type II	20°C to 25°C (68°F to 77°F)	168 hr
o	TT-S-735, Standard Test Fluids; Hydrocarbon, Type III	20°C to 25°C (68°F to 77°F)	168 hr
p	TT-S-735, Standard Test Fluids; Hydrocarbon, Type VII	20°C to 25°C (68°F to 77°F)	168 hr
q	Dielectric-Coolant Fluid, Synthetic Silicate Ester Base, Monsanto Coolanol 25 or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
r	MIL-T-81533, 1, 1, 1 Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing	20°C to 25°C (68°F to 77°F)	168 hr
s	Azeotrope of Trichlorotrifluoroethane and Methylene Chloride, Dupont Freon TMC or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
t	MIL-G-3056, Gasoline, Automotive, Combat	20°C to 25°C (68°F to 77°F)	168 hr

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Solderability: See paragraph 4.6.3.
Smoke: 250°C ± 5°C (482°F ± 9°F); no visible smoke.
Smoke quantity: D_S-20 min. shall not exceed 5.0 for 22 AWG.
Spark test of primary insulation: Not applicable.
Surface resistance: 5 megohms - inches (min), initial and final readings.
Thermal index: 200°C min for 15,000 hours (qualification only).
Thermal shock resistance:
Oven temperature, 200°C ± 3°C (392°F ± 5.4°F).
Maximum change in measurement, 0.060 inch.
Wrap back test: No cracking, no dielectric breakdown, oven temp. 200 ± 3°C (392 ± 5.4°F).

Flammability requirements and procedure:

The flammability test of MIL-W-22759 shall be modified for the wire of this specification sheet as follows: The specified test burner shall be used without the wing top flame spreader and shall be adjusted to furnish a 3-inch conical flame with an inner cone approximately 1 inch in height and a temperature of 955°C ± 30°C (1751°F ± 54°F) at its hottest point. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9-1/2 inches below the marked point on the wire specimen in the test chamber and at least 1/2 inch above the floor of the chamber. The period of application of the hot flame tip to the marked point on the wire specimen shall be 30 seconds for all sizes of wire. Observations shall include time of burning after removal of the test flame, final distance of flame travel on the wire above the test mark, and presence or absence of flame in the facial tissue due to incendiary drip from the specimen. Requirements shall be:

Duration of after-flame	3 seconds (max)
Flame travel	3.0 inches (max)
No flaming of tissue	

Breaking of the wire specimen in size 24 or smaller shall not be considered as failure provided the requirements for duration of flame, final distance of flame travel, and absence of incendiary dripping are met.

One specimen shall be tested from each sample unit. The post-flame dielectric test of MIL-W-22759 is not required for wire of this specification sheet.

Immersion procedure:

A 24-inch specimen for each test fluid in Table III shall have its diameter measured and shall then be immersed to within 6 inches of each end for the time and temperature specified. During immersion, the radius of bend of the wire shall be not less than 14 nor more than 35 times the specified maximum diameter of the wire under test. Upon removal from the test fluid, the specimen shall be wiped dry and then remain for 1 hour in free air at room temperature. The diameter shall be measured and compared to the initial diameter. The insulation shall be removed for a distance of 1/2 inch from each end of the specimen. The specimen shall then be subjected to the bend test and dielectric test specified in the procedure for life cycle testing.

Qualifying activity: The activity responsible for the qualified products covered by this specification sheet is Naval Avionics Center, Code B/714, 6000 East 21st Street, Indianapolis, IN 46219-2189.

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC, PTFE, FLUOROCARBON/POLYIMIDE, PTFE INSULATED, NORMAL WEIGHT, SILVER COATED COPPER CONDUCTOR, 200°C, 600 VOLTS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the wire described herein shall consist of this specification and the latest issue of MIL-W-22759

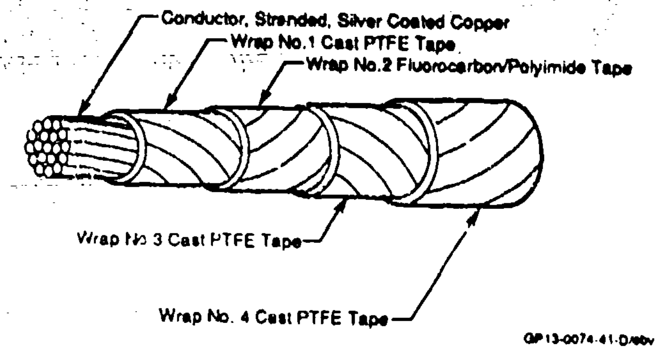

Figure 1. General Configuration

TABLE I CONSTRUCTION DETAILS

Part No. 1/	Wire Size (AWG)	Conductor: Stranding (Number of Strands X AWG Gauge of Strands)	Conductor: Diameter (in.) Min	Conductor: Diameter (in.) Max	Finished Wire: Resistance at 20°C (ohms/1,000 ft) (Max)	Finished Wire: Diameter (in.) Min	Finished Wire: Diameter (in.) Max	Finished Wire: Weight (lb/1,000 ft) (Max)	Insulation Tapes: Wrap 1 Tape Code	Insulation Tapes: Wrap 2 Tape Code	Insulation Tapes: Wrap 3 Tape Code	Insulation Tapes: Wrap 4 Tape Code
M22759/ -24-*	24	19 x 36	0.023	0.024	24.300	0.039	0.043	2.0	2/ 50% MOL	3/ 66% MOL	4/ 50% MOL	
M22759/ -22-*	22	19 x 34	0.029	0.030	15.100	0.044	0.048	3.2				
M22759/ -20-*	20	19 x 32	0.037	0.038	9.190	0.053	0.057	4.6				
M22759/ -18-*	18	19 x 30	0.046	0.048	5.790	0.063	0.067	7.0			60% MOL	
M22759/ -16-*	16	19 x 29	0.052	0.054	4.520	0.069	0.073	8.7				
M22759/ -14-*	14	19 x 27	0.065	0.068	2.880	0.086	0.089	13.6	5/ 66% MOL		50% MOL	
M22759/ -12-*	12	37 x 28	0.084	0.087	1.900	0.105	0.109	20.5				
M22759/ -10-*	10	37 x 26	0.106	0.110	1.190	0.129	0.133	32.0				
M22759/ -8-*	8	133 x 29	0.158	0.166	0.658	0.182	0.187	57.0				
M22759/ -6-*	6	133 x 27	0.198	0.208	0.418	0.225	0.229	89.0		6/ 60% MOL		
M22759/ -4-*	4	133 x 25	0.250	0.263	0.264	0.277	0.282	140.0				
M22759/ -2-*	2	665 x 30	0.320	0.340	0.170	0.358	0.364	238.0	7/ 50% MOL	5/ 60% MOL	6/ 60% MOL	4/ 50% MOL
M22759/ -1-*	1	817 x 30	0.360	0.380	0.139	0.383	0.406	300.0				
M22759/ -01-*	0	1045 x 30	0.395	0.425	0.108	0.438	0.444	378.0				
M22759/ -02-*	00	1330 x 30	0.440	0.475	0.088	0.492	0.496	475.0				

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1/ Part number: The asterisks in the part number column, Tables I and II, shall be replaced by color code designators in accordance with MIL-STD-681 except that for sizes 2 and larger, the braid color shall be dark green and the designator shall be 50. Examples: Size 20, white with orange stripe - M22759/ -20-93; size 2, dark green - M22759/ -2-50. Printing of color code designator on surface of wire insulation is not required.

2/ Tape code: 1.6 - Cut thru resistant, heat resealable, cast PTFE tape, 0.0016" max. thickness.

3/ Tape code: 1.25 - 0.0001" PTFE fluorocarbon resin/ 0.001" polyimide film/ 0.0001" PTFE fluorocarbon resin, 0.00125" max. thickness.

4/ Tape code: .85 - Laser markable, heat sealable, cast PTFE tape, 0.00085" max. thickness.

5/ Tape code: 2.0 - Heat resealable PTFE tape, 0.002" max.

6/ Tape code: 2.0 - 919 polyimide film, 0.002" max.

7/ Tape code: 1.5 - Heat resealable PTFE tape, 0.0015" max.

MOL - Minimum Overlap

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

FSC 6145

TABLE II. TEST MANDREL AND TEST LOAD REQUIREMENTS

Wire Size (AWG)	Test Mandrel Diameter 1/ (in.)			Test Load 1/ (lb)	
	Life Cycle	Bend Tests	Wrap	Life Cycle	Bend Tests
26	0.250	0.250	0.125	0.50	0.50
24	0.250	0.250	0.125	0.50	0.50
22	0.250	0.250	0.125	0.75	0.75
20	0.250	0.250	0.125	0.75	0.75
18	0.375	0.375	0.250	1.00	1.00
16	0.375	0.375	0.250	1.00	1.00
14	0.500	0.500	0.375	2.00	2.00
12	0.750	0.750	0.375	2.00	2.00
10	0.750	0.750	0.375	3.00	3.00
8	2.000	2.000	1.000	3.00	3.00
6	4.500	4.500	2.500	3.00	3.00
4	6.000	6.000	3.000	4.00	4.00
2	6.000	6.000	4.000	6.00	6.00
1	8.000	8.000	4.000	6.00	6.00
0	8.000	8.000	6.000	6.00	6.00
00	10.000	10.000	6.000	8.00	8.00

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TABLE III. MARKING AND COLOR DURABILITY TEST LOADS

Wire Size (AWG)	Test Load 1/ (grams)
26 2/	75
24 2/	75
22	100
20	100
18	150
16	150
14	150
12	150
10	150
8	150
6	150
4	150
2	150
1	150
0	150
00	150

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1/ Tolerance shall be +/- 3 percent of the given values.

2/ Marking is not applicable.

RATINGS:

Temperature rating: 200°C (392°F) maximum continuous conductor temperature.
Voltage rating: 600 volts (rms) at sea level.

ADDITIONAL REQUIREMENTS:

Acid resistance: No requirement.
Arc propagation: No propagation or tracking (qualification only).
Blocking: 230°C ± 3°C (446°F ± 5.4°F).
Color: In accordance with MIL-STD-104, class 1; white preferred. For braided constructions, color shall be dark green within Munsell color limits of 5Y 3/2 and 5B 2/0.5. Conformity of color to the limits of MIL-STD-104 shall not be required after crosslinking proof test or life cycle oven exposure.
Color striping or banding durability: 125 cycles (250 strokes) (min), Table III. Not required for sizes 2 and larger.
Dielectric test after immersion: 2500 volts (rms), 60 Hz.
Flammability: Quality conformance test, group II. For requirements and procedures see below.
Humidity resistance: After humidity exposure, wire shall meet the requirements for initial insulation resistance.
Identification of product: Not required for sizes 24 and smaller. Color code designator not required.
Identification durability: 125 cycles (250 strokes) (min), Table III. Not required for sizes 2 and larger.
Immersion: For procedure see below.
Impulse dielectric test: 8.0 kilovolts (peak), 100 percent test.
Insulation resistance, initial:
  Sizes 26 through 10, 5000 megohms for 1000 feet (min).
  Sizes 8 through 00, 3000 megohms for 1000 feet (min).
Insulation thickness: 0.0075 inch minimum
Lamination sealing: Oven temp 230 ± 2°C (446 ± 3.6°F) for 48 hours.
Life cycle: 500 hours at 230°C ± 3°C (446°F ± 5.4°F). Dielectric test, 2500 volts (rms), 60 Hz. Procedure to use mandrels coated with polytetrafluoroethylene in the form of either enamel or wrapped tape, such that the diameter of the mandrels, after coating, still conform to the requirements of performance details, Table II.
Low temperature (cold bend):
  Bend temperature, -65°C ± 3°C (-85°F ± 5.4°F).
  Dielectric test, 2500 volts (rms), 60 Hz.

TABLE III. IMMERSION TEST FLUIDS

	Test Fluid	Test Temperature	Immersion Time
a	MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	48°C to 50°C (118°F to 122°F)	20 hr
b	MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance	48°C to 50°C (118°F to 122°F)	20 hr
c	TT-I-735, Isopropyl Alcohol	20°C to 25°C (68°F to 77°F)	168 hr
d	MIL-T-5624, Turbine Fuel, Aviation, Grade JP-4	20°C to 25°C (68°F to 77°F)	168 hr
e	MIL-A-8243, Anti-icing and Deicing-Defrosting Fluid, Undiluted	48°C to 50°C (118°F to 122°F)	20 hr
f	MIL-A-8243, Anti-icing and Deicing-Defrosting Fluid, Diluted 60/40 (Fluid/Water) Ratio	48°C to 50°C (118°F to 122°F)	20 hr
g	MIL-C-43616, Cleaning Compound, Aircraft Surface	48°C to 50°C (118°F to 122°F)	20 hr
h	TT-M-268, Methyl Isobutyl Ketone (For Use in Organic Coatings)	20°C to 25°C (68°F to 77°F)	168 hr
i	SAE-AS-1241, Fire Resistant Hydraulic Fluid for Aircraft	48°C to 50°C (118°F to 122°F)	20 hr
j	MIL-L-7808, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	118°C to 121°C (244°F to 250°F)	30 min
k	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Undiluted	63°C to 68°C (145°F to 154°F)	20 hr
l	MIL-C-25769, Cleaning Compound, Aircraft Surface, Alkaline Waterbase, Diluted 25/75 (Fluid/Water) Ratio	63°C to 68°C (145°F to 154°F)	20 hr
m	TT-S-735, Standard Test Fluids; Hydrocarbon, Type I	20°C to 25°C (68°F to 77°F)	168 hr
n	TT-S-735, Standard Test Fluids; Hydrocarbon, Type II	20°C to 25°C (68°F to 77°F)	168 hr
o	TT-S-735, Standard Test Fluids; Hydrocarbon, Type III	20°C to 25°C (68°F to 77°F)	168 hr
p	TT-S-735, Standard Test Fluids; Hydrocarbon, Type VII	20°C to 25°C (68°F to 77°F)	168 hr
q	Dielectric Coolant Fluid, Synthetic Silicate Ester Base, Monsanto Coolanol 25 or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
r	MIL-T-81533, 1, 1, 1 Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing	20°C to 25°C (68°F to 77°F)	160 hr
s	Azeotrope of Trichlorotrifluoroethane and Methylene Chloride, Dupont Freon TMC or Equivalent	20°C to 25°C (68°F to 77°F)	168 hr
t	MIL-G-3056, Gasoline, Automotive, Combat	20°C to 25°C (68°F to 77°F)	168 hr

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Shrinkage: 0.125 inch (max) at 230°C ± 3°C (446°F ± 5.4°F).
Solderability: See paragraph 4.6.3.
Smoke: 250°C ± 5°C (482°F ± 9°F); no visible smoke.
Smoke quantity: D_S-20 min. shall not exceed 5.0 for 22 AWG.
Spark test of primary insulation: Not applicable.
Surface resistance: 500 megohms - inches (min), initial and final readings.
Thermal index: 200°C min for 15,000 hours (qualification only).
Thermal shock resistance:
Oven temperature, 200°C ± 3°C (392°F ± 5.4°F).
Maximum change in measurement, 0.060 inch.
Wrap back test: No cracking, no dielectric breakdown, oven temp. 200 ± 3°C (392 ± 5.4°F).

Flammability requirements and procedure:

The flammability test of MIL-W-22759 shall be modified for the wire of this specification sheet as follows: The specified test burner shall be used without the wing top flame spreader and shall be adjusted to furnish a 3-inch conical flame with an inner cone approximately 1 inch in height and a temperature of 955°C ± 30°C (1751°F ± 54°F) at its hottest point. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9-1/2 inches below the marked point on the wire specimen in the test chamber and at least 1/2 inch above the floor of the chamber. The period of application of the hot flame tip to the marked point on the wire specimen shall be 30 seconds for all sizes of wire. Observations shall include time of burning after removal of the test flame, final distance of flame travel on the wire above the test mark, and presence or absence of flame on the facial tissue due to incendiary drip from the specimen. Requirements shall be:

Duration of after-flame	3 seconds (max)
Flame travel	3.0 inches (max)
No flaming of tissue	

Breaking of the wire specimen in size 24 or smaller shall not be considered as failure provided the requirements for duration of flame, final distance of flame travel, and absence of incendiary dripping are met.

One specimen shall be tested from each sample unit. The post-flame dielectric test of MIL-W-22759 is not required for wire of this specification sheet.

Immersion procedure:

A 24-inch specimen for each test fluid in Table III shall have its diameter measured and shall then be immersed to within 6 inches of each end for the time and temperature specified. During immersion, the radius of bend of the wire shall be not less than 14 nor more than 35 times the specified maximum diameter of the wire under test. Upon removal from the test fluid, the specimen shall be wiped dry and then remain for 1 hour in free air at room temperature. The diameter shall be measured and compared to the initial diameter. The insulation shall be removed for a distance of 1/2 inch from each end of the specimen. The specimen shall then be subjected to the bend test and dielectric test specified in the procedure for life cycle testing.

Qualifying activity: The activity responsible for the qualified products covered by this specification sheet is Naval Avionics Center, Code B/? , 6000 East 21st Street, Indianapolis, IN 46219-2189.

F-33615-89-C-5605

VOLUME II

NEW INSULATION CONSTRUCTIONS
FOR
AEROSPACE WIRING APPLICATIONS

CONTRACT F-33615-89-C-5605/P00005

AMENDMENT NO. 2

Inclusive pages: (Complete) Title page, ii-xviii, 1-201

SUPPLEMENTARY

INFORMATION

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WRIGHT LABORATORY (AFSC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6523

Errata AD-A 240638 6 May 1992

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Please change subject report(s) as follows:

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WM F. WHALEN
Chief, Tech. Editing & STINFO Branch
Resource Management

2 Atch
Pgs 5-109 & 5-110, WL-TR-91-4066, Vol I

FIGURE 5.42 - WEIGHT LOSS (OUTGASSING) TEST SETUP

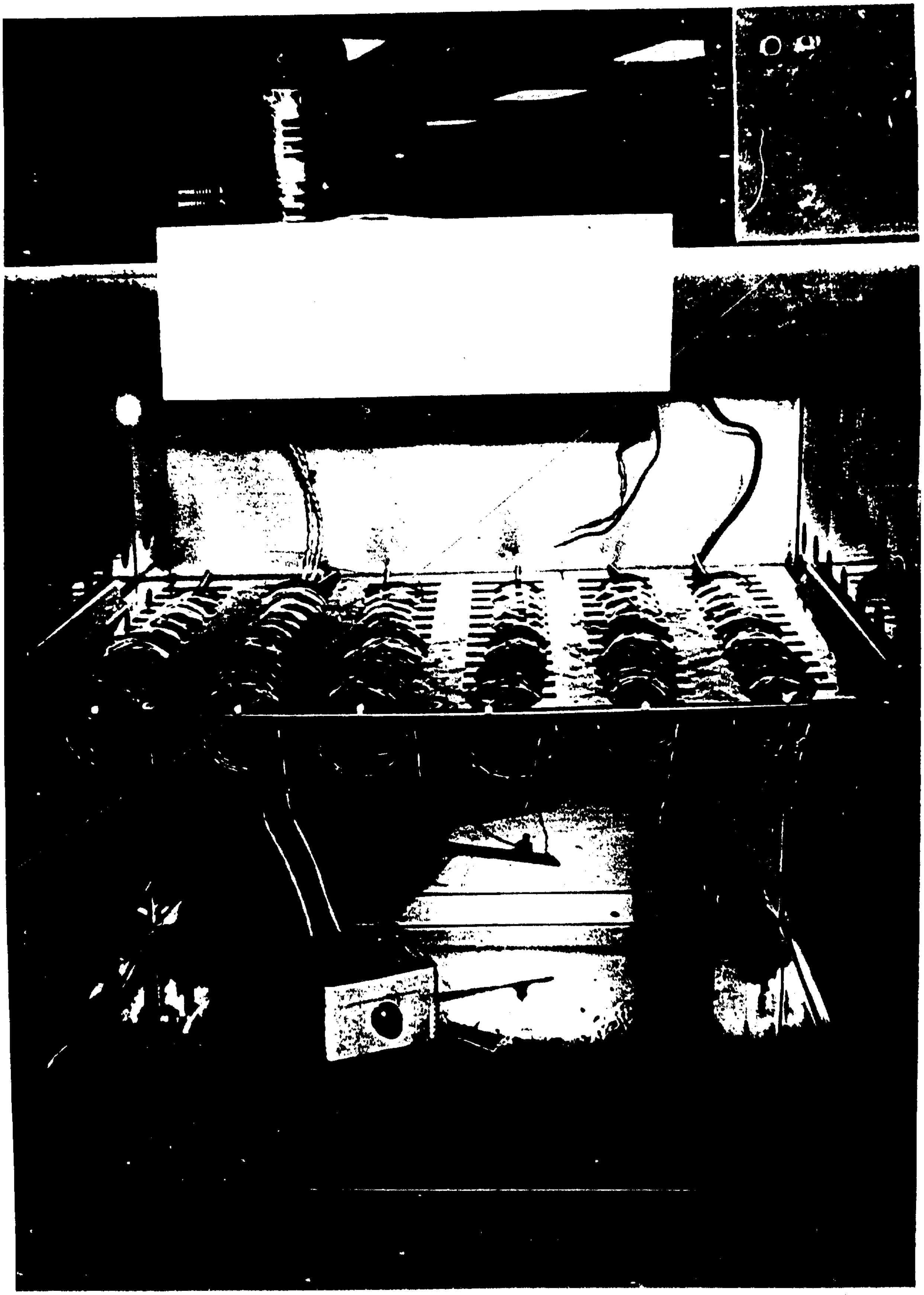

FIGURE 5.43 - WEIGHT LOSS (OUTGASSING) 5% R.H. TEST SPECIMENS